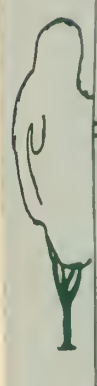


Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.

SD 11
A32
(~~SD 11~~)

SD 11
26 Feb
1966



ASD 11

A32

SD 11
6 Flo
1966

FORESTRY RESEARCH PROGRESS 1966

by
William H. Cummings
and
Philip N. Joranson



**McINTIRE-STENNIS
COOPERATIVE FORESTRY
RESEARCH PROGRAM**

USDA
FOREST SERVICE
LIBRARY
JAN -5 P 5:36
McINTIRE-STENNIS
BRANCH

Contents

	Progress Statement	Page
Introduction	- - -	1
FOREST BIOLOGY		
Soils	1-15	2
Physiology	16-45	5
Ecology	46-54	15
GENETIC IMPROVEMENT		
Variation and selection	55-69	17
Breeding	70-81	20
SILVICULTURE		
Seed, regeneration	82-92	24
Timber stand improvement	93	27
Specialty products	94-99	27
Special plantings	100-106	30
FOREST PROTECTION		
Fire	107-109	33
Pathology	110-132	34
Entomology	133-153	42
FOREST MANAGEMENT		
Timber management	154-161	46
Mensuration	162-172	48
Site	176-180	51
Aerial techniques, survey	181-184	52
Recreation	185-202	54
Wildlife	203-221	59
Range	222-229	64
Watershed	230-236	66
Multiple-use	237-244	68
FOREST UTILIZATION		
Logging	245-246	71
Wood properties	247-283	71
Manufacture, design	284-294	81
Seasoning, preservation	295-302	84
Pulp, composite products	302-308	86
FOREST ECONOMICS		
Policy	309-316	89
Marketing forest products	317-330	92
Projects, Progress and Participating Scientists, McIntire-Stennis Program		95

Introduction

Nineteen-sixty-six was the third year of research under the McIntire-Stennis Cooperative Forestry Research Program*. On July 1, 1966, the Federal appropriation was increased from \$2,500,000 to \$3,000,000 annually. Well established programs are active at 60 State institutions. They are well coordinated among each other and with the Forest Service (Department of Agriculture) and other programs in the 50 States and Puerto Rico.

During the year, the 330 problems which are being pursued required the combined efforts of 421 senior scientists, and participation in a number of the projects afforded excellent research training experience to 361 graduate students preparing for forestry research careers. Results of research were described in 195 publications, averaging about 3.3 per institution. How these numbers of projects, of senior scientists, of graduate students receiving training, and of publications describing progress are divided among the participating institutions is shown in the Appendix.

The project leaders in the McIntire-Stennis program include many widely recognized scientists and promising men who have received their training recently. A high percentage of leaders hold doctoral degrees.

+ + + + + + + + + + + + + + + + +

*Compiled from reports received from participating institutions. Special acknowledgement is made to the following research specialists in Cooperative State Research Service for their cooperation in preparing certain sections of the report: Henry A. Dunn, Entomology; Arthur S. Newman, Soils, John F. Fulkerson, Pathology; Donald R. King, Wildlife; Harlow J. Hodgson, Range; Glenn R. Smith, Products Marketing; and, Alvin T. M. Lee, Recreation.

FORESTRY RESEARCH PROGRESS IN 1966

McIntire-Stennis Cooperative Forestry Research Program

Forest Biology

Soils

Soils related research basic to forestry represents a significant part of the McIntire-Stennis program. In all, 15 projects report progress in research on the following major topics: (a) response of forest trees to fertilizers, (b) the effects of nutrients on plant analysis, forest litter, and the soil, (c) nutrient-water relationships, and (d) the chemical and physical characterization of forest soils.

1. Among investigations underway on the fertilization of forest soils, the University of Washington project on nitrogen effect on Douglas fir covers experiments started as much as 16 years ago. Growth measurements on all plots in the study, involving about 200,000 individual trees were completed in March 1966. Computer analysis of volume growth for all plots through the 1965 growing season is now in progress. Growth response from various increments of nitrogen is being assessed over a range of ages, sites, and management practices. Response by Douglas fir under the environmental conditions of the plots in this study continue to be good. Nitrogen additions of 100 to 400 pounds per acre have resulted in growth averaging 50 percent greater than on control plots. Total response apparently continues for at least 5 years from one application. The applied nitrogen apparently is strongly retained within the forest system and is subject to practically no leaching loss. Results from this study have stimulated considerable interest in nitrogen fertilization of Douglas fir. Now some operational work is being undertaken but a great deal more information is needed on a number of aspects of nitrogen fertilization before application in forest practice.

2. In Pennsylvania the amount of calcium, phosphorus and nitrogen added in the spring of both 1963 and 1964 has strongly influenced the levels of these nutrients found in the foliage of white and scarlet oaks after the 1965 growing season.

3. In Maine research is underway on the physiological growth responses of white pine to nitrogen, phosphorus, and potassium in greenhouse and field experiments. Analysis and correlation of foliar nutrient elements with tree growth and soil nutrients will be made. Chemical analysis of white pine seedlings treated with varying concentrations of water and nutrients is nearly completed. Other phases of this project deal with the relation of soil properties to (a) the growth characteristics of balsam fir, (b) the occurrence of major forest types in Maine and (c) the prediction of productivity of forest land.

4. In an Ohio study of yellow-poplar fertilization, nitrogen produced the greatest response. Trees fertilized with nitrogen stayed green and retained their leaves later in the fall than trees not receiving nitrogen -- similar to leaf retention reported by Tennessee last year.

5. In Hawaii the growth of Australian toon, tropical ash, saligna eucalyptus, and slash pine with different rates of nitrogen, phosphorus and potassium fertilizer has been evaluated on two sites with broken lava rock as the dominant feature of the land. Generally, nitrogen and phosphorus are the nutrients which need to be supplied. The maximum tree height with fertilization was obtained with flooded-gum which reached a height of 16.6 feet in one year. Slash pine, the slowest growing tree, reached only 2.6 feet in 18 months with optimum fertilization.

6. In Oklahoma the fertilization of catalpa determined in three soils under greenhouse conditions showed the following growth responses: none with phosphorus only, limited with nitrogen only, but highly significant increases with nitrogen and phosphorus combined.

7. In a Tennessee study fertilizer stimulated the growth of yellow-poplar, sweetgum and loblolly pine seedlings more than irrigation, and, best growth was obtained where both treatments were applied. Northern red oak seedlings, however, showed no response to either treatment. In the natural yellow-poplar stand fertilizer doubled the diameter growth on the lower slope position while irrigation had no effect. On both upper and lower slope positions the combination treatment provided the greatest stimulus to height growth.

8. In Florida slash and loblolly pines after three growing seasons averaged 0.8 feet higher on a fixed water table of 18 inches than on one of 36 inches. On an uncontrolled water table, slash pine had an average height of 2.7 feet and loblolly only 1.7 feet. Trees fertilized with 500 pounds per acre diammonium phosphate (18-48-0) averaged 27 percent higher than the unfertilized on the 18-inch water

table, 14 percent higher on the 36-inch water table, and 19 percent higher on the uncontrolled water table. At the end of the first growing season, slash pine on a Leon soil prepared by ridging averaged 27.1 inches in height, compared with 17.8 inches for trees on areas that were chopped, harrowed or remained untreated. Ridging had concentrated organic matter in the soil depth where the seedling roots developed.

9. At Humboldt State College the neutron soil moisture meter is being used to establish soil moisture depletion curves. These will be useful to wildland managers in assessing the impact of vegetation manipulation on plant growth and development and on water yield and runoff characteristics. Periodic remeasurement of soil moisture is made on established plots so as to obtain an accurate record of moisture depletion and recharge.

10. Investigations on the role of the shrubby alder (Alnus crispa) in nitrogen nutrition of forests were initiated by the University of Alaska. Soils are being analyzed from stands of quaking aspen, white spruce, mixed aspen and alder, mixed spruce and alder, and pure alder.

11. Also in Alaska further examination was made of the progressive decline in nitrogen status of black spruce in the successional stages on north slopes. When growing in the mixed paper birch-alder stands, black spruce contained 1.11 percent nitrogen in the foliage. The black spruce growing on sphagnum bogs on these slopes had foliage that showed only 0.75 percent nitrogen content. A similar decline is indicated for phosphorus status except that only in the sphagnum bogs does phosphorus reach deficient levels in the foliage of black spruce.

12. The study by the University of Michigan on the role of thin textural bands in the C horizon of outwash sands on the site productivity for jack pines was completed this year. Several hundred field observations were represented by 67 plots on which a condensed summary is tabulated below:

| Textural-band
Classification | Plots
number | Site-Index
(50 years)
feet | Basal Area
per acre
sq. ft. |
|---|-----------------|----------------------------------|-----------------------------------|
| Absent | | | |
| throughout | 31 | 39-58 | 70-110 |
| Developed below 42"
(weakly or strongly) | 24 | 45-66 | 80-120 |
| Strongly developed
throughout profile | 12 | 50-71 | 110-140 |

The degree of development of textural bands showed a consistent relation to site index, and basal area, and to an enhanced degree to the product of volume of the jack pine stands. Roots develop more intensively and water content is greater in soil just above the bands.

13. In Hawaii investigation of properties of soils in plots of Australian toon indicated that this tree is best adapted to younger and more fertile soils. It shows little relationship to soil physical properties and available potash, unlike the previously-analyzed saligna eucalyptus. As found for the indigenous forests, the soils analyzed in the Australian toon plots show 5 to 15 times as much exchangeable potash in the topsoil as in the subsoil. Soils too stony and rough for large-scale cropping or pasture, may be suitable for the production of this tree.

14. The University of Montana study of silica deposits (opal phytoliths) in plant foliage which are returned to the soils upon plant decay is continuing. Procedures for the isolation and identification of opal phytoliths have been developed. Studies have been made of the amount of silica in leaf tissue of various species, and of changes in content with time in needles of a number of conifers. This research provides background for the reconstruction of the history of different plant communities which have occupied a site.

15. At Louisiana Polytechnic Institute nuclear methods will be employed to measure the less permeable layer of two forest soil profiles.

Physiology

When we gain full basic knowledge about what takes place within the living cells and systems of cells in trees, we may be able to realize some of the hopes for manipulating tree growth for greater efficiency of production. Today forest tree physiologists are among forest scientists who are in great demand and short supply. The McIntire-Stennis Program can assist substantially with both the research and the graduate training of additional researchers. The unsolved problems in forest tree physiology may qualify as the most intellectually challenging to be found in biological science today. Research now in progress dealing with a variety of problems is grouped in the following by similar types of subjects for reporting current results. On photosynthesis -- the basic conversion of energy of sunlight for plant growth -- five institutions conducted research in 1966.

16. A University of Washington project yielded significant evidence on the existence of functional and non-functional parts of the crown of Douglas-fir. Previous investigations had shown little net assimilation in the bottom portion of crowns and the loss of annual rings in lower branches. In 1966 a detailed and carefully controlled pruning and assessment of subsequent growth dynamics was carried out. This showed that removal of the non-functional part of the crown had no effect upon the growth of the tree stem; however, removal of the upper or functional portion had a substantial effect.

17. The Iowa project deals with differences in rates of photosynthesis and growth of eight Scotch pine seed sources, ranging from 42° to 66° north latitude and grown in the greenhouses under a 16-hour photoperiod for approximately 6 months. Rates were strongly related to latitude of seed source; however, seedlings with the highest rate of photosynthesis per gram of needle weight grew the least. Therefore for the eight sources studied, a selection for high photosynthetic efficiency would be a selection for slow growth. This ambiguity may be resolved by re-examining photosynthetic efficiency and its relationship to needle development. In this study, seedlings less adapted to the 16-hour photoperiod used probably produced fewer needles immediately following the cotyledon stage, and thus produced less photosynthate over any given interval of time. Photosynthate that was produced was used to a greater degree in the maintenance of existing protoplasm. Thus, quantity of photosynthate available for new cell wall construction and carbohydrate storage was reduced in the less-adapted seed sources. Therefore, the ratio of photosynthesizing protoplasm to stored carbohydrates, cell wall and non-photosynthetic protoplasm was greater in the less-adapted seedlings. Because of this the less-adapted seedlings appeared to have a higher photosynthetic efficiency. Seed source and light intensity had an interacting effect on rates of photosynthesis only in seedlings of the two northernmost seed sources.

18. Two researchers at the Connecticut Agricultural Experiment Station are trying to learn the cause of the low net level of photosynthesis in tree leaves as compared to the high efficiency of the leaves of crop plants. Some results suggested that tree species which absorb CO₂ slowly in bright light compared to an efficient absorber such as maize also have a rapidly functioning glycolic acid oxidase system (for the release of energy through respiration) which leads to a large internal CO₂ evolution in the light. The more efficient species lacks this rapid oxidase system. Thus, the basic photosynthetic capacity of efficient and inefficient absorbers may be identical and their difference may be in the amount of respiratory CO₂ which the inefficient species must reassimilate. This, in turn, depresses absorption of CO₂ from the atmosphere. To test whether blocking the glycolic acid oxidase system could actually lead to greater efficiency, a metabolic inhibitor of glycolic acid oxidase was fed to leaves of an inefficient species.

Unfortunately, however, the inhibitor also suppressed photosynthesis. In addition, the researchers studied the effect of light intensity, wavelength of light, CO₂ concentration, temperature and inhibitor concentration on glycolic acid formation in a convenient test plant, tobacco, helping to design experiments on trees where leaves are only available part of the year.

19. At the State University College of Forestry at Syracuse University, New York, an experiment is under way that utilizes one-year-old seedlings of white ash girdled in a variety of ways and grown in light (2800 f.c.) and dark (12 f.c.). This indicated that, contrary to what is generally assumed, photosynthate is even more important than storage products in elongation as well as radial growth during the first 30 days of seedling growth. Buds of one-year-old white ash seedlings became active rapidly when brought into a growth chamber following a 90 day chilling period (a parallel study with red pine was terminated due to heavy losses to a root rot). Very soon after mitotic activity appears in the bud and before the bud expands noticeably, the cambium beneath the bud base begins to divide. Commonly the cambium is active along 2 arcs that are in a plane at right angles to the plane of attachment of the outermost pair of bud scales. The cambial stimulus then moves down the stem into the roots.

20. Research is starting in South Carolina on the effect of moisture stress upon the rate of photosynthesis and respiration of loblolly and shortleaf pine seedlings.

21. This is one of two projects at the University of Michigan dealing with the movement and conversion in other parts of the tree of sugar formed by photosynthesis in tree leaves. Conclusions have been drawn from analysis of several thousand tissue samples taken from young trees of bigtooth aspen growing in the forest. Initial sugars synthesized by newly expanding leaves are retained within the leaf and go largely into cellulose of leaf tissue. In two weeks, current photosynthates move from the two-week old leaves toward the tip of the developing shoot and there go into cellulose of younger leaves. Within four weeks there is an abrupt shift from upward to downward transport, and current photosynthate from four-week old leaves moves to cambial and root activity.

22. A second project at the University of Michigan deals with carbohydrate incorporation into wood cells during growth of the annual ring. It has been found that water stress affects directly the amount of sugar incorporated into wood cells. Radioactive sugar was incubated with differentiating wood tissues which had been removed from the stems of mature pine trees, and water stress was imposed in the tissue with an osmotic agent. Increases in water stress reduced the incorporation

of sugar into wood cell walls. Since these tissue were separated from the foliage of the tree, it was indicated that part of the decrease in growth of wood cells associated with drought is a direct effect of water stress, and that not all the reduction is due to lowered growth substances translocated to the cambium from the crown.

23. In a somewhat similar project in Ohio, wood cells of the rose plant are being grown in tissue culture and the effects of many substances on cell dimensions are being studied. The effects of various levels of kinetin, gibberellin, naphthalene acetic acid, calcium, magnesium, potassium, adenine, sucrose, thiamine, pantothenic acid, pyridoxine, nicotinic acid, sorbitol, inositol, cytidylic acid, guanylic acid, folic acid and vitamin B₁₂ in the culture medium on the size of the cells of rose have been examined. Except in experiments involving removal of potassium from the medium, no statistically significant effect on the length or width of the cells could be discovered. Growth of the cells at different temperatures did not cause any significant change in their size. In addition, 23 media which had allowed shoot development in cultures of other tissue were tested and found to have no significant effect on the size of cells of rose tissue or to cause shoot development in the cultures. In an experiment where potassium was omitted from the medium and the cells were no longer growing, the average length of the cells was 77 microns compared to 59 microns in the presence of potassium and the average width was 64 microns in the absence and 45 microns in the presence of potassium. The corresponding average volume of a cell grown in the presence of potassium was 0.06 mm³, and in the absence of potassium was 0.17 mm³. A method for the separation of clumps into single cells has been established and shown not to affect the dimensions of the cells.

24. This project at Auburn University is one of two recently initiated that focuses on the activity of basic cellular directive substances, RNA, or ribonucleic acid. The objective is to correlate changes in RNA levels in treated leaves and the activity of the associated enzyme ribonuclease with resistance of woody plants to the herbicide 2,4-D. Work is in progress with red maple, sweetgum, and yellow-poplar.

25. A study in Missouri will deal with mimosa transfer ribonucleic acids following irradiation.

Water effects on the tree growth and survival is an aspect of physiology dealt with in nine McIntire-Stennis studies. Most of the research is addressed to measurement and reduction of the large amounts of water lost from tree leaves through transpiration.

26. This project of the School of Forestry, University of Missouri, determined that upland hardwood stands used about 0.17 inches of water per day during the late spring and summer. Short period extremes varied from approximately 0.33 inches per day to less than 0.10 inches per day. The total moisture loss by evapotranspiration for May, June, July, and August was 19.5 inches. The net moisture loss from the soil by evaporation and transpiration for this 4-month period exceeded rainfall by approximately 7.5 inches. Changes in soil moisture were measured to a depth of 81 inches. Apparently very few roots penetrated deeper than 69 inches, however, since virtually no change occurred in the moisture content of the soil below that depth. Daily evapotranspiration values are similar to those reported for a fescue meadow in the same area.

27. In the Nevada project, instead of actual moisture loss the rate of sap movement in the stem was measured by portable instrumentation on two white firs and two Jeffrey pines. Rate of sap movement was much lower in July 1966 than in July 1965 which was a wet year. During winter months withdrawal of soil water by firs and pines was nearly continuous, in contrast to virtually discontinued withdrawal by brush species and willows.

28. A new study at the Oregon State University will deal with variation in transpiration of Douglas-fir seedlings that may relate to survival of seedlings in the field.

29. The project at the Connecticut Agricultural Experiment Station is one of two on the effects of chemicals on intake of water and on loss through the stomata. The progress report indicated that closure of stomata by a spray of phenylmercuric acetate (PMA) had previously decreased the transpiration from small, isolated jack pines and increased the leaching of water from the lysimeters in which they grew. Now the procedure has been tested in a plantation of 45-foot red pines on a deep, sandy soil. In early June, trees in 8 replicates were sprayed from the ground with 1000 gallons/acre of 1mM PMA. The solvent did not infiltrate sprayed trees as well as the unsprayed trees, thus verifying the stomatal-narrowing effect of the PMA. Diurnal shrinkage of stem diameter was decreased by stomatal narrowing. The change in soil moisture was measured by a neutron meter to depths of 6 or 11 feet at 96 sites and indicated a significant 0.8 inch decrease in evapotranspiration where stomata had been narrowed. The decrease was observed in the first 5 weeks after spraying.

30. In the Wisconsin project several substances were tested for effect on the permeability of roots to water and on internal water relations. Permeability of roots of decapitated jack pine seedlings was increased by octenylsuccinic acid. Succinic acid with more than 8 carbon atoms

did not increase root permeability. Root permeability of seedlings probably was increased because of injury by the chemicals. Immersion of roots of 1-0 red pine seedlings in various succinic acids (with 8 to 18 carbon atoms) injured roots and increased their permeability. Octenyl and decenylsuccinic acids were most toxic. Leaf sprays of decenylsuccinic acid did not improve internal water relations of 2-0 white ash seedlings or 8-year-old red pine plantation trees. Here toxicity to pine was evident with 0.5 M concentrations. Decenylsuccinic acid, applied by dipping leaves, was toxic to sugar maple seedlings at concentrations of 0.01 M or greater, and of little immediate apparent effect at concentrations of 0.001 M or less.

31. Studies are continuing at the University of Alaska on the effects of soil temperatures on moisture availability for growth of white spruce. Soil kept free of snow reached a minimum temperature at the 4-inch depth of -25.4°C on January 16. Under natural snowfall (maximum depth during winter was 35 inches on plots) the minimum temperature of -7.8°C was reached two months later on March 16. A 6-inch layer of straw mulch under snow was not effective in maintaining warmer soil temperatures during winter but significantly reduced the rate of thawing of the soil in the spring. Aside from a one or two day delay in the initiation of transpiration in the spring on the cold soil plots, no significant effect of the soil temperature differences observed on moisture relations or growth of the white spruce trees was detected.

32. Of three projects on soil moisture effects on growth and survival, one at the University of Illinois reports on moisture gradients through minor changes in topography that have considerably influenced the composition of upland forests in central Illinois. In eight forest areas studied, sugar maple ranged from a position of dominance to one of complete absence as sites became progressively drier. As sugar maple declined in importance, its place was taken by white oak and black oak. In woodlands where sugar maple is a major species, its place in future stand composition appears to be one of increasing importance because of the large number of seedlings and saplings present. Combinations of drought and air temperatures in the 90° - 100°F . range caused high mortality of sugar maple, red oak, and white oak seedlings in a study of the effects of shade and soil moisture on the relative rates of photosynthesis and respiration. In contrast, the high survival of bur oak may have some ecological significance, as this species has been considered a "pioneer" in past invasions of the prairie by forest trees.

33. A second University of Illinois project deals with the effects of soil moisture stress upon growth and wood characteristics in loblolly pine. Reporting is postponed due to instrumentation delays.

34. A study recently initiated, in South Carolina deals with soil moisture and fertility that are limiting factors in the growth of forest trees on dry uplands of the Piedmont.

35. The University of Idaho project on root development in relation to survival and growth of coniferous seedlings reports current results. When planning forestation programs the rooting patterns of both the tree species to be planted and the competing vegetation occurring on the site should be taken into account. At Idaho, root development of ponderosa pine seedlings planted either without site preparation or on scalped areas ranging up to 50 inches in diameter was studied with the aid of radioactive P^{32} over a two-year period. Initial results ~~that~~ have now been evaluated reveal that while rooting depth of seedlings reached 24 inches during the first growing season, the most active absorption occurred within 8 inches of the soil surface. Radio-analysis of foliage tissue from competing vegetation showed that roots of forbs and shrubs growing outside the scalped areas ~~had~~ exploited this same zone to a much greater extent than did grasses. More extensive competition control may thus be necessary on ponderosa pine planting sites dominated by shrubs and forbs than on those dominated by grasses.

36. In a project at Mississippi State University, preliminary analysis of the growth of the main axis meristems of loblolly pine indicates a correlation between the maximum rates of shoot elongation and the time interval between these rates, for the successive flushes of growth.

37. A study in North Carolina is designed to learn the effects of wind sway on tracheid length and specific gravity of loblolly pine.

38. Of three projects on nutrition of forest trees, the research at the University of Maine on northern white-cedar involves comprehensive analyses of the nutrient element content, fresh and dry weight, and pulping characteristics of all parts of the tree. This is a follow-up on similar research reported last year on other important native trees. The contribution of specific information should enhance utilization of the timber resource. Currently only a very small percent of the available northern white-cedar is cut for shingles and posts. None of it is being used for paper or paper products.

39. At Michigan State University preparations are being made with black walnut and Scotch pine seedlings of varying geographic origins, to determine rates of nutrient assimilation by the tree, the nutrient pathway from root to crown, and nutrient distribution and concentration throughout the tree.



Fig. 1- Dr. Mark Behan examines symptoms of nitrogen deficiency of 1-year-old western larch in irrigated sand cultures. University of Montana, Statement 40.

40. This project in Montana aims at devising a system to assess mineral deficiencies of western larch. This system would be adapted for use in diagnosing and correcting nutritional problems of western larch encountered in the field. This research, illustrated by Figure 1, reported progress as follows: Western larch exhibits unusually distinctive visual mineral deficiency symptoms, and a scheme for their detection based on chemical analyses of the foliage and visual symptoms has been developed, using greenhouse grown plants. Research to correlate these symptoms with field responses to fertilization is underway. The growth of western larch under controlled conditions disclosed several other important features. Extension of the photoperiod to 19 hours by artificial light had a major stimulating effect on shoot elongation, permitting plants grown with optimum mineral and water supplies to attain a height of about 5 feet in one year. Also, the onset of autumn leaf drop and dormancy could be postponed by extending the photoperiod at greenhouse temperatures. Spur shoot foliage typical of the species develops only on axillary buds subjected to a period of dormancy. Buds that continue development the season they are formed become branches rather than spur shoots.

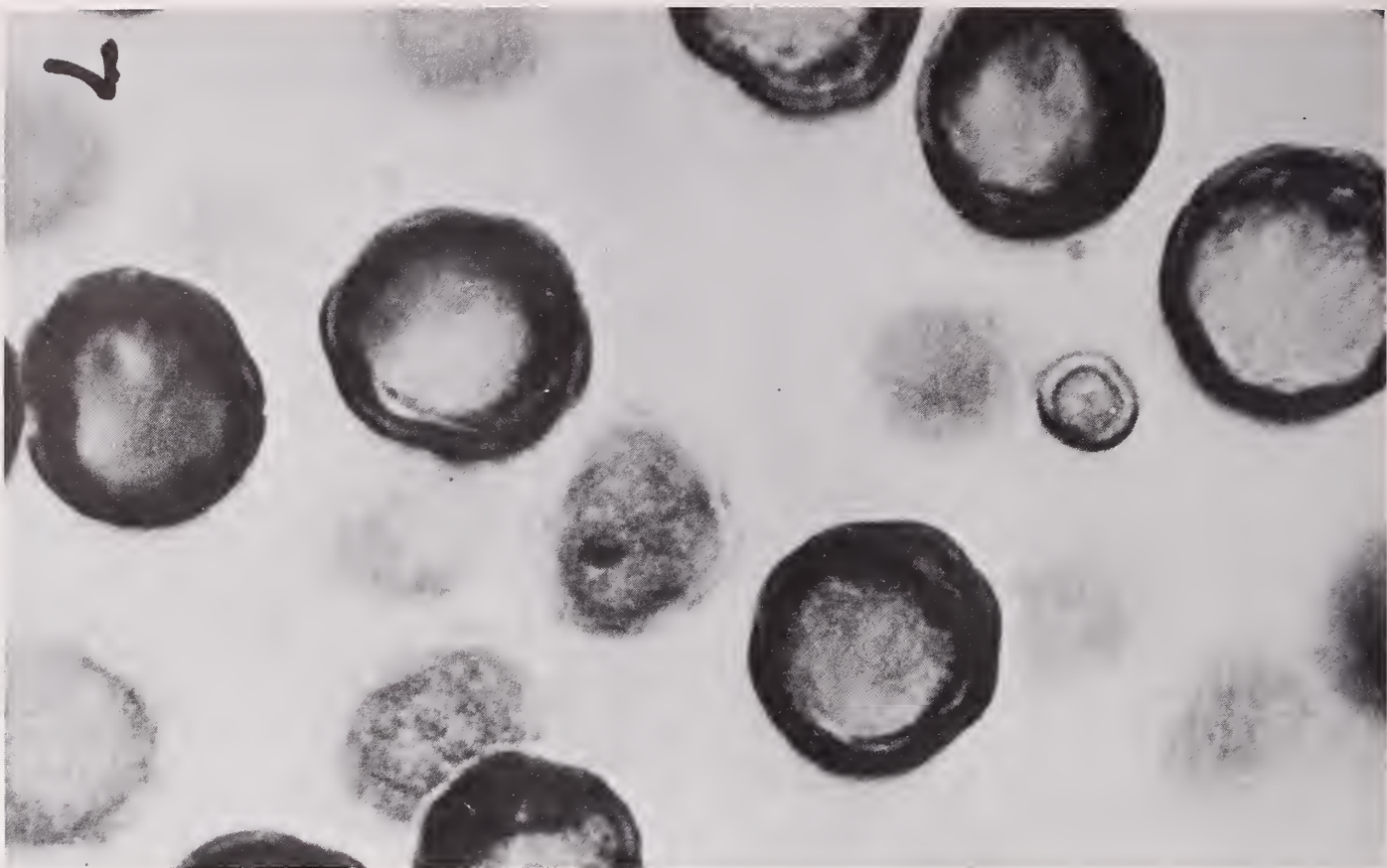
41. In the Florida study on nitrogen nutrition in relation to reproduction responses of slash pine, foliage, bark, and wood tissues for different cone numbers in response to nitrogen have been assayed. Total nitrogen and phosphorus ranged from 1.3 and 0.2 to 0.45 and 0.07 percent respectively, for foliage and wood tissues. Bark tissues differed most in total N between treatments and between 1- and 2-year old tissues. Differing activity and quantity of ribonuclease were observed in the pine buds. Cone counts confirmed the non-random distribution on pine trees at the Gainesville orchard with directional dominance of east over west, and counts at Olustee showed this east dominance.

42. A study at Georgia deals with bud development, shoot elongation, cambial activity and reproduction in sweetgum. Floral development began with bud formation in mid-September; the mixed bud remained dormant over winter. Meiosis in the microsporangium occurred from March 15 to April 5; with enlargement of floral parts concurrent, and pollen was released in mid-April. Meiosis of the megaspore mother cell started May 1 and fertilization was completed by May 15 (See Figures 2 and 3). Seed dispersed from early September throughout the winter. Vegetative buds formed on short shoots by June 1 and on long shoots by August 15. Cambial activity at breast height ranged from May 15 to August 15.

43. A study at Maryland aims to reproduce pine species vegetatively from needle fascicles. Attempted rooting of 8 pine species was greatest in Austrian pine fascicles without buds collected in May 1965, rooting was 43 percent by January, and 58 percent by November 1966. No new shoot growth occurred. Rooted cuttings potted in an illuminated 40° room to break bud dormancy showed Swiss Mountain pine and Austrian pine rooted satisfactorily; no loblolly pine produced roots.

44. At the College of Forestry, Syracuse University, a study dealt with how cold treatment of dormant seeds makes them germinable, and biochemical requirements for germination of non-dormant seeds. Abscissin II, a recently discovered plant growth regulator, was synthesized to study effects on the germination of both dormant and non-dormant ash seeds. It inhibited germination, leaf growth and chlorophyll synthesis in non-dormant seeds and seeds whose dormancy was overcome by cold treatment.

45. A study at North Carolina on the competition between genotypes deals with light in the forest, and toxins. On light in the forest a technique is described for preparing and using alkaline-petroleum-ether solutions of chlorophyll to measure the number of calories of photosynthetically active light striking the surface. Field tests reveal that even under dense canopy, light could compensate for respiration. Total basal-area per acre serves as an accurate estimator of the quantity of light transmitted through a forest canopy.



Stages in the floral development of sweetgum (George Foster Peabody School of Forestry, University of Georgia, Statement 42).

Fig. 2 (above) - Mature pollen grains 450 X

Fig. 3 (below) - Mature embryo sac: A, the egg nucleus, and B, the fused polar nucleus. 500 X.



Other phases deal with (a) juglone in the ecology of walnut and associated plants; and (b) physiology of variation in 10,000 potted progenies of 30 families of loblolly pine.

Ecology

46. In an Oregon study on secondary forest succession, soil moisture, stress alone did not damage Douglas-fir seedlings under varied conditions of shade, aspect, and climatic zone; however, herbaceous competition caused drought that on south slopes eliminated Douglas-fir completely.

47. Of 5 projects on the composition of forest vegetation, the one in Oregon deals with internal water stress patterns of 1-to 2-meter Douglas-fir and Shasta red fir trees on a study area. Values range from 3 atmospheres in a Shasta red fir-mountain hemlock stand to 28 atmospheres in a Douglas-fir-California black oak stand; all cambial growth ceased at 25 atmospheres. Potential soil fertility tested by growth of 5-month old seedlings showed soils derived from ultrabasic material were infertile, while those derived from graphite mica schist produced top yields.

48. In the University of Alaska study of composition and structure of forest and muskeg permanent transects were established across transitions between four forest-muskeg pairs, with sampling of vegetation and underlying soil and peat.

49. The Purdue University study of techniques for forest ecosystem evaluation focuses on ordination of vegetation communities. Using the 3-dimensional ordinations rewritten for the FORTRAN IV program, 48 Indiana forest stands were ordinated and plotted. Data from 19 annual remeasurements of a single woodland by the Forest Service, U. S. Department of Agriculture, have been ordinated. Research plots established in 15 forest stands representing a successional gradient were sampled vegetationally, and by major insect groups at two day intervals.

50. A Montana project deals with photo interpretation of understory vegetation.

51. The Northern Arizona University study of past vegetation and climate focused on reconstructions from quaternary pollens in lake sediment of the Coconino Plateau. Modern pollen rain is sampled to supplement the fossil and reference pollen counts.

52. How available soil moisture influences the distribution of plants and animals under study in Montana provided data collected for three years, at each of seven sites or eco-units, on vegetation, soil and air temperature and moisture. Detailed studies deal with birds of the ponderosa pine-fir and the lodgepole pine ecosystems on opposite slopes; chipmunk behavior and physiology; effects of clear cutting and animal populations; and determining whether plants present after burning developed from seed in the duff or as suckers from the roots.

53. The University of California project on the ecological potential of redwood reports on the relative response of redwood which with Douglas-fir and tan oak is subject to inundation by periodic flooding in the environment of alluvial flats. Two-year-old redwood seedlings subjected to prolonged flooding showed (a) no change in turgidity of needles and internal water balance; however, (b) abnormal yellowing of new needles and killing of most of the roots. Upon soil drainage these seedlings rapidly regenerate root system from living old roots. To predict response of older redwood to flooding, seven-year-old trees were planted in seven-foot-tall metal cylinders and subjected to different flooding routines. Within 24 hours after flooding anaerobic conditions prevailed throughout the flooded soil. Flooding stimulated (a) root growth in the unflooded portion of the cylinders and inhibited it in the flooded portion, and (b) height top growth for the first 60 days only. When 60 percent of the soil profile was flooded, there was no stimulation in height growth; but inhibition occurred after 45 days. The larger volume of new roots following flooding, confirmed the ability of redwood to regenerate new roots, as when roots are buried by silting.

54. A study by the University of Delaware of the impacts of urbanization on small hardwood areas reported on six woodlots being compared. Mice, voles and squirrels are conspicuous mammals and the wood thrush the dominant nesting bird. Along rapidly urbanizing highways, the rate of woodlot disappearance has trebled during the past 3 years in New Castle County. Remaining woods are subjected to dumping, disturbance of forest floor, cutting of trees, and construction of "huts" and camp fires. On the public health hazards of urban woodlots, sampling indicates that certain mosquitoes may be potential vectors of encephalitis from birds to man. Yellowjacket wasps, hazardous to sensitive picnickers have nest sites in variable understory throughout upland woods. Striped skunks, have destroyed 80 percent of these wasp nests over a two year period.

Genetic Improvement

Variation and Selection

The total research enterprise mobilized for the genetic improvement of forest trees in this country is now considerable, and is a closely coordinated field of forestry research. State institutions play a large role and are working with both conifer and hardwood species. Our forest industries and some of the State forestry departments in major timber regions have espoused genetic tree improvement research as a must. Accordingly, the past fifteen years have seen much research put to immediate use in practical programs to produce genetically improved tree seed. To determine the degree or causes of variation, or to select desirable types, or both, is the principal objective of fifteen projects. These are widely distributed and deal with an increasing number of commercially important tree species, both conifers and hardwoods.

55. Michigan State University reports that results from mineral analyses of foliage of several species for geographic origins within species show considerable genetic variation. In ponderosa pine from 44 to 83 percent of the total variance in nitrogen, potassium, phosphorus, calcium, boron, and zinc is accounted for by differences in regions of origin. In a 20-origin study of Virginia pine 2 seedlots from the far South accounted for most of the variability in nutrient content of needles and also suffered pronounced winter injury. Recent analyses for Scotch pine indicate that seed source and rate of height growth are related to resistance to the European pine sawfly. In the physiological variation of Austrian pine nitrogen fertilization has little effect on height growth or anatomical characteristics. Although composition is influenced by nitrogen, growth rate appears to be unrelated to foliar nutrient level.

56. Washington State University reports that lodgepole pine occupies vast areas of forest land in the four states involved in this study. Its characteristic of multinodal growth (successive bursts of tip growth) may be of great importance for any specific management objective, such as Christmas trees, lumber or pulpwood. Field work was completed in Washington, Oregon, Idaho, and Montana, and resulted in a complete characterization of 176 selected parent trees which will provide the basis for a model of the parent to which its half sib progeny can be compared. Controlled pollinations among individuals of two distinct sources -- uninodal, and a group expressing 2, 3, and 4 nodalness numbered 242. Seed was collected and sown to produce 400

uninodal, 5,000 binodal, 560 trinodal, and 600 quadrinodal plants. Efforts to produce rooting from needle fascicles were partly successful, 16 to 20 percent, using combinations of indolebutyric acid and kinetin or adenine.

57. The North Carolina project as one of seven dealing with southern pines, reports progress on the following objective: To determine the patterns of variation found in natural stands of Caribbean pine (located in the Bahama and Caicos Islands) and slash pine (located in Florida) and to determine the relationships that exist among the taxa of this complex.

58. The Auburn University project reports on the development of improved forest trees. Open pollinated progenies from 18 plus loblolly pines were tested for resistance to Cronartium fusiforme. There was no indication of high resistance to the disease $3\frac{1}{2}$ months after inoculation. Modified nurse seed grafting, a new method, was successfully used for propagating large-seeded oaks. Approximately 50 percent success was obtained with trials of 300 chestnut oak and 100 pin oak grafts. The method is simple and easy and shows promise of becoming useful for propagating oaks, chestnuts, pecans, and walnuts.

59. In the project at Oklahoma State University on development of improved trees, rootstock for 12 acres of shortleaf and 6 acres of loblolly pine breeding orchard was planted. In a study of cultural methods, results to date indicate that for a dry year, application of nitrogen at the rate of 160 pounds per acre and potash at the rate of 60 pounds per acre is detrimental to both survival and initial height growth of loblolly and shortleaf seedlings planted in heavy grass sod. Scalped spots and sawdust mulch combined provided highest survival and greatest height growth. In another phase of the project, 26 select shortleaf pine and 6 select loblolly pine have been located and evaluated phenotypically.

60. In a second project at Oklahoma State University, seed collections have been made from 104 trees, representing the range of shortleaf pine in Oklahoma for the seed source and open-pollinated heritability study.

61. In the genetic studies in native and exotic tree species of importance to forestry in South Carolina, one aim is to establish seed orchards of loblolly pine and yellow-poplar. Evaluation continues on 60 select loblolly pine trees. Eastern redcedar seedlings of 16 provenances planted in December 1965 showed survival in August 1966 that averaged over 80 percent. Deodar cedar seed lots have presented a problem in germination.

62. The Florida project deals with slash pine. In September 1966, cones were collected from the remaining disease-free trees in a plantation that had been rogued three years ago to remove the 90 percent of trees infected with southern fusiform rust. Seedlings obtained will be exposed to fusiform rust to determine the relative inherent resistance passed on by these parents. Seeds were also obtained from slash pines judged superior in growth and form, and seedlings from these sources will also be exposed to fusiform rust to determine value of the parents for use in a breeding program for improved rust resistance.

63. In a project with Douglas fir at Oregon State University, the aim is to determine genetic variation in photosynthetic efficiency at age 2 years in the field and under laboratory conditions. Seedlings from the 1966 crop are being raised in greenhouse and will be tested in 1968. Development of a temperature controlled cuvette utilizing the Peltier effect for temperature control is in progress. Although the 1965 crop was small, it was possible to reach some preliminary conclusions as to wide crosses. Crosses between trees from Willamette Valley and the high Cascades resulted in reduced vigor and early cessation of growth when compared to open pollinated progeny from Valley trees, but somewhat increased growth when compared to progeny from high Cascade trees.

64. A West Virginia University study in progress deals with hardwoods. Seed of black cherry--the valuable cabinet wood--has been collected from 26 sources throughout its range. Time of bud break in the spring appears to be weakly correlated with growth rate. Black locust clones were selected from dominant stem and multiple stem types. Vegetative propagation technique tests show considerable variation in the ability of excised roots to produce cutting material or to strike roots. Planting seedlings has been much more successful than direct seeding in forest openings. The greatest growth was obtained in the largest openings.

65. Progress is reported from the project at the Agricultural Experiment Station of Clemson University where southern red oak is being improved. Acorn collections sown in a State nursery displayed germination ranging from good to poor. A count late in the summer showed 60 satisfactory lots of more than 100 seedlings. Growth of the seedlings produced was satisfactory. In the fall of 1966, acorns were solicited anew from 22 cooperators located in the 12 states covering the range of species with the hope of providing additional lots of seedlings.

66. In the sugar maple study at Michigan Technological University, nursery stock from the range-wide seed collections were shipped to the Northern Forest Genetics Laboratory of the Forest Service for treatment in the radiation field. Measurements of variation show specific gravity differences with length of growing season from 80 to 140 days in Michigan.

67. A Wyoming study, where aspen is a major big game feed, measured growth in aspen exclosures, and noted ecotypes based on leaf-shape.

68. In a Florida study of graftage techniques 3 growth chemicals tested on scions of 5 hard-to-graft slash and loblolly pine on 2-0 stock were inconclusive--but nitrogen applied to stock showed promise.

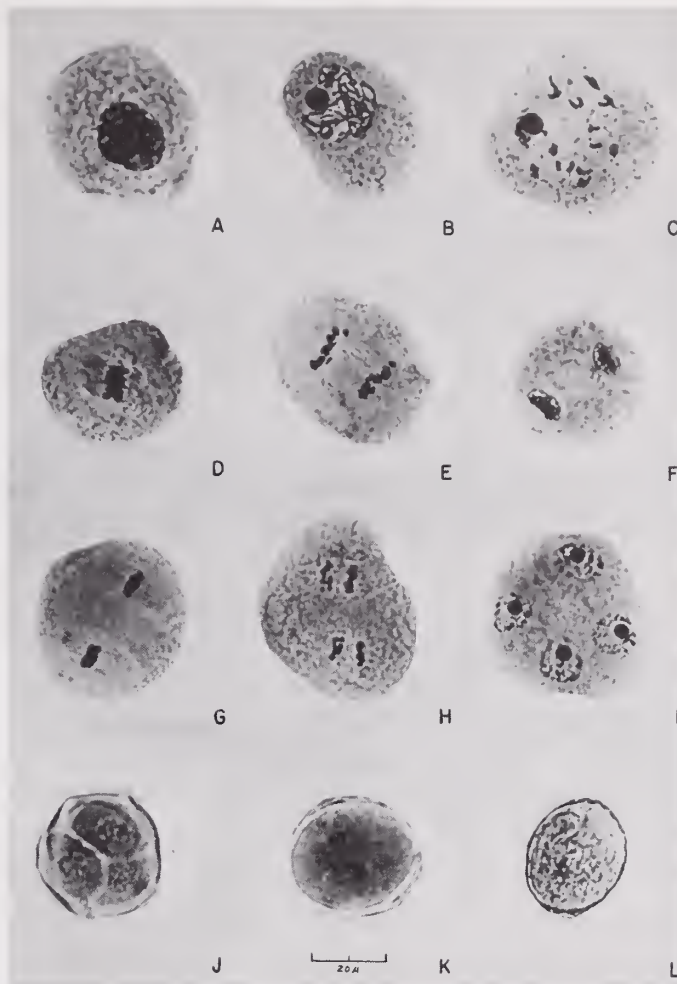
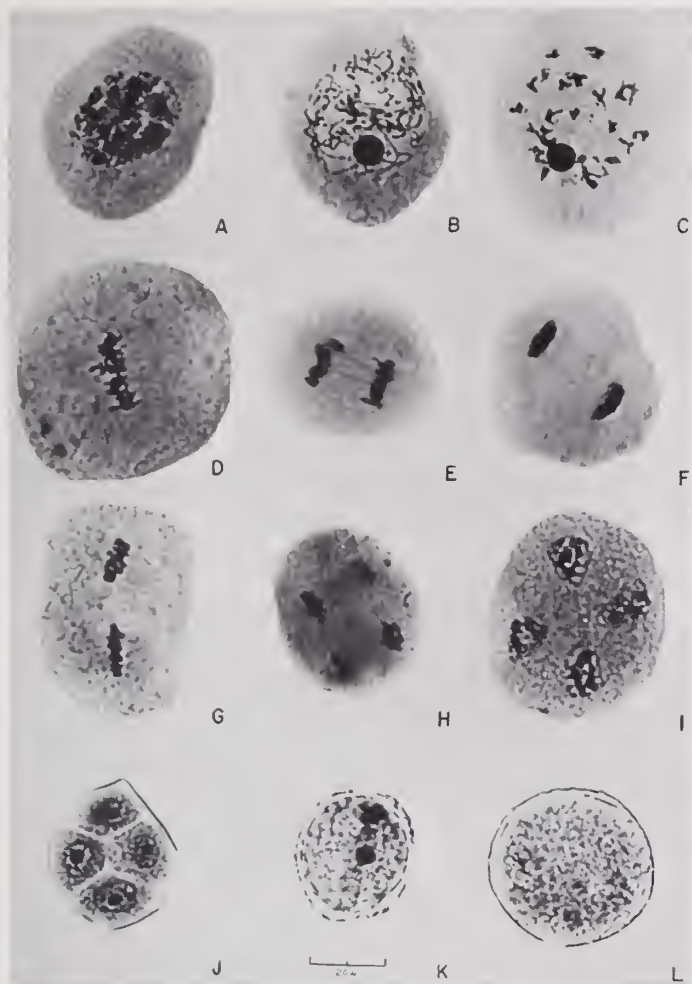
69. In a University of Michigan study of variation in yellow birch and other native birches, 725 collections of foliage from 6 species and 5 hybrids show 12 suspected hybrids of white and yellow birch--chromosome number and pairing confirmed the hybrid identity of two of these. Study of 160 yellow birch, 39 bog birch, and 8 of their hybrids showed 20 percent overlap in flowering date that could account for hybrids in nature, and pollen was uniform for the two species.

Breeding

70. A study at Minnesota deals with promising aspen and poplar crosses. From January to May, 45 out of 90 controlled crosses succeeded. Most of these involved parents from widely separated Minnesota populations of quaking aspen. Already detected was an apparent correlation between females and crossing success. Crosses between full-sibs, and unrelated quaking aspen were made to detect any depression of growth from breeding--though none appeared in first season growth.

71. In the Montana study of larches, crosses between western larch, maternal parent, and Japanese larch produced a small amount of small sized but apparently sound seed.

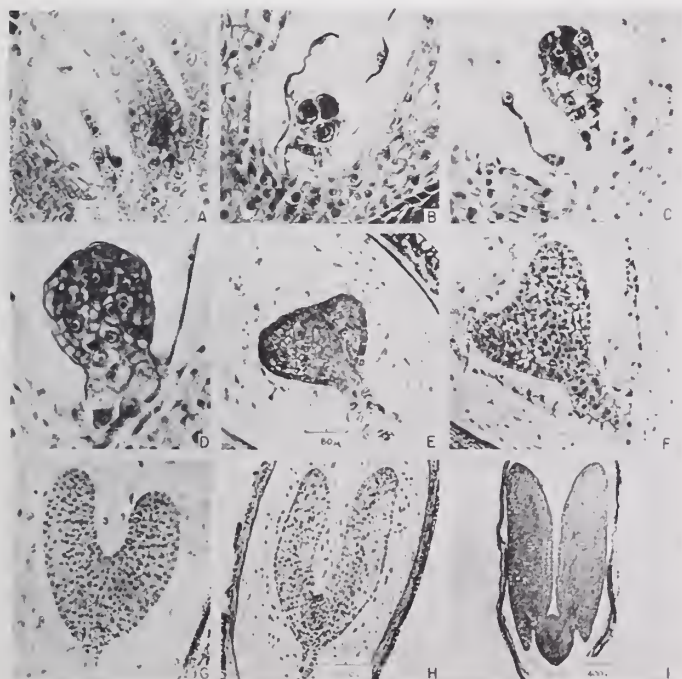
72. Of seven studies on reproduction, one at Syracuse deals with the reproductive cytology of black cherry, and similar comparison tetraploid American elm and diploid Scotch elm in a search for a disease-resistant elm hybrid. The breeding of intraspecific hybrids of yellow-poplar was initiated in cooperation with the Forest Service.



Aspects of reproduction in elm
(State University College of
Forestry at Syracuse University,
Statement 72).

Fig.4-(Above) Development of elm
pollen grains. American elm,
chromosome number 56, A to L,
on left; Scotch elm, chromosome
number 28, A to L, on right.
A through I show chromosome
divisions leading to the four
pollen grains shown in J; and
K, L, show the mature pollen
grains.

Fig.5-(on left) Seed development
in American elm. A shows embryo
sac; B to H, the developing
embryo prior to the mature stage,
in I.



Institute of Forest Genetics at Gulfport, Mississippi. Initially hybrids between Mississippi and New York populations appear cold-hardy in New York, though seedlings from Mississippi parents are not.

73. A study in Wisconsin aims to overcome the barrier to crossing red pine with other pine species by use of pollen mixes. Greenhouse seedlings from 1964 controlled pollination on red and Austrian pines, that used varied pollen mixes, lack inter-specific hybrid indications.

74. At the Ohio Agricultural Research and Development Center, cross-ability barriers between eastern white, Korean, and Swiss stone pine, did not prevent fertilization and beginning of embryo development.

75. A Colorado State University study finds that Engelmann spruce cones become receptive to pollen one week before those of blue spruce, and Engelmann spruce mother trees are more successful than blue spruce trees in producing artificial hybrids between the two species. Other hybrid seedlings originated from crosses on Rocky Mountain Douglas-fir mother trees of Oregon male parents produced twice as much first-year height as progeny of local wind pollination origin.

76. At Missouri, pine cones produced under contrasting controlled humidity and temperature regimes at the time of pollination are being dissected to examine seed development.

77. In a study of flower induction on juvenile Douglas-fir at Oregon State University, enclosures are being developed to maintain desired air temperatures about previously non-fertile seedlings.

78. A second Oregon study compares development of Douglas-fir seed from high and low elevations. Seed maturation appear determined more by environment, particularly temperature, than by heritable factors--although operative in the early bud burst of low elevation scions on high elevation stock trees. High-elevation trees and their scions grafted on low-elevation stocks showed marked differences in the development of the embryos of the seed produced.

79. In the study at Idaho on heritability of characters and population structure of ponderosa pine, controlled crosses made involved 590 bags on 14 trees with 8 pollen sources. The completed survey of natural populations of ponderosa pine in 14 States and Canada provided material for a 1000-seed-source provenance study of variation of genetic characters under uniform conditions. Needle specimens showed distinct differences in stomatal characters related to geographic origin.

80. In the University of Washington study of a single gene in development of the tomato as model plant, transfer of the lanceolate gene (causing low numbers of flowers per inflorescence and few seed per fruit) to a desirable background (high numbers of flowers per inflorescence and many seed per fruit), resulted in a first backcross generation with the expected increase in numbers in both traits.

81. In the South Carolina study of inbreeding Virginia pine, seedling production from self-pollinated seed lots varied from 0 to 25, compared with open-pollinated lots from 0 to 100.

Red pine reproduction study area (University of Minnesota, Statement 85)

Fig. 6- Before disking.



Fig. 7- Mileacre plots with exclosures installed.



Silviculture

Silviculture is the time honored field of forestry defined as the theory and practice of controlling forest establishment, composition, and growth. The research activities reported on 25 projects are assigned to four groups with the following numbers of progress statements: 11 on regeneration -- including seed, planting, and nursery research, 1 on brush control, 6 on special tree products -- Christmas trees, naval stores, and essential oils, and 7 on windbreaks, special plantings and dendrology.

Seed, Regeneration

82. Constantly plagued by wild fire, drought, erosion, invading brush, rodents and sporadic seed crops, the problem of securing dependable regeneration of Jeffrey pine forests on the East Slope Sierra Nevada remains a battle of risks. Regeneration by artificial seeding seems nearly hopeless in the new Nevada study. Despite baiting with poisoned grain at 10 pounds per acre, the loss to rodents amounted to nearly all of the endrin-coated seed. The fewer than one percent of the tagged seed that germinated by May all succumbed to the summer drought. Test plantings of Jeffrey pine on three areas show early differences. Fall planting that is relatively easy, when followed by a dry year suffered disastrous loss. With no removal of competing brush, survival averaged 6 percent. By contrast, spring planting with some reduction of competing brush by herbicides survived best -- averaging 46 percent. It seems plain that the big "if" is water, and the odds are significantly improved by: (a) spring planting, (b) in soils at field capacity, (c) with killing of competing vegetation, and (d) reduction of evaporative stress.

83. What species are adapted to erosive sites on the high East Slope of the Sierra Nevada? In a new test in Nevada, preliminary plantings of conifers showed survival of the first year that was poor and declined in the order: Jeffrey pine, Douglas-fir, lodgepole pine, and sugar pine. Sugar pine on duff cover and north aspect was poorest. New plantings, scheduled to commence following precipitation this fall, should bring out effectiveness for erosion control.

84. The influence of elk and cattle on reforestation with Douglas-fir and ponderosa pine is a newly launched study in Idaho. The treatments of spring seeding and fall planting of both species resulted in sufficient survival to evaluate animal influences. The seedling mortality attributable to trampling resulted from concentrated use by elk in the spring before July 1 and by cattle after September 10. A less-esteemed

animal, the pocket gopher, proved a major factor in the rodent contribution to seedling mortality. Plans call for further seeding and planting with ancillary weather observations in the field, simulated animal damage treatments in the greenhouse. Integration of these data should facilitate the appraisal of animal influence on reforestation from this research.

85. Environmental factors related to the failure of red pine reproduction, is a new project in Minnesota that will deal with both natural and direct seeding. In this first season, the major effort was to establish plots, and field installations. In all, nine plots in each of four replications were screened to exclude rodents, and moisture barriers of polyethylene were installed to isolate the treatment effects (See Figures 6 and 7). Rain gauges, soil moisture probe access tubes, and snow stakes were installed. Fall seeding has been completed. Seed trap studies showed 1966 to be another fail year for red pine seed. Seedlots from 1957, the last good year, and 1963, a moderate year with germination testing 83 percent and 94 percent, respectively, were acceptable for seeding the experimental plots. Weather records for the 1966 growing season (May-September) indicate above normal precipitation (+2.27") and slightly below normal temperature (-0.7°F.). Neutron moisture probe measurements (P_v) at the 6-inch depth varied only from 19.2 percent to 13.5 percent. Driest levels in the soil profile occurred at the 36 inch depth, reaching a low of 7.6 percent; however, this is still above the wilting point for these loamy-sand soils. The surface foot of soil exhibits the greatest moisture fluctuation due to evapotranspiration and precipitation. During the 1966 season, however, moisture was not a limiting factor to red pine reproduction.

86. The development of planted black walnut, yellow-poplar, and hybrid poplar in the Purdue project continues to show response to weed control and fertilization in the root zone at time-of-planting. Little response resulted from broadcast fertilization and green manuring in comparison with untreated "old field" sites after two growing seasons. On bottom-land sites, the reduction of weed competition, especially by chemical control, stimulates early growth of seedlings, with foliage of improved size, color, and nitrogen content. Effective treatments are strikingly illustrated in growth of test plantings. Hybrid poplar with weed control after two seasons averaged 17 feet in height and 1.8 inches in diameter, while trees on untreated areas were 11 feet in height with less than 1 inch diameter. Black walnut on a clean cultivated site attained heights up to 10.6 feet in three years. Also these field trials have revealed problems worthy of investigation for production of high-quality black walnut.

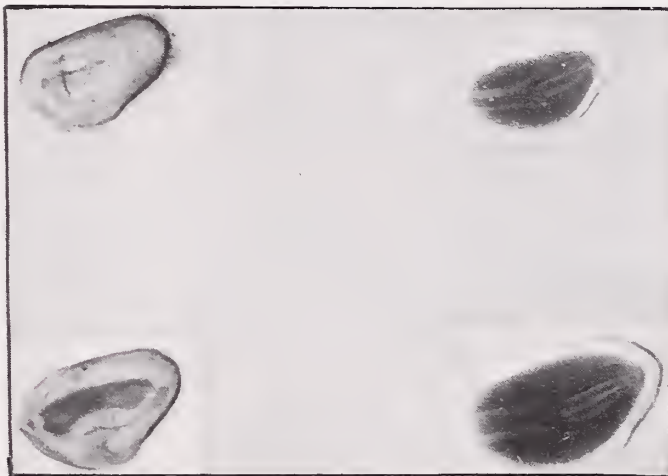
87. Research on optimizing site conditions for the establishment and growth of high quality black walnut was launched this year by Michigan State University. This involves establishment of site-modification



treatments for test plantings, measurement of superior plantations of 20 to 60-year age in Michigan, seed collection from selected trees, and initiating nursery production from seed lots for regional provenance plantings.

88. In the research on hardwood planting on upland old fields by Southern Illinois University, fertilization promoted growth of more vigorous seedlings, and the control of weeds is proving prerequisite.

89. The seed X-ray research at Clemson concentrates on optimizing the correlation with actual germination. In the case of longleaf pine seed from 69 sources, this correlation was improved if the X-rayed seed was treated, prior to germination test, by an algicide. Subsequently tests on the pine seed discovered the presence of other microorganisms potentially hindering the germination. These included 10 species of identified fungi, and one unidentified yeast. (See Figures 8 and 9). Studies on yellow-poplar seed from four sources deal with the influence of stratification upon the correlation with germinability.



X-raying quality of longleaf pine seed in the Forestry Department .
(Agricultural Experiment Station of Clemson University, Statement 89).

Fig. 8-(upper) Forest physiologist McGregor reads a seed X-ray film.

Fig. 9-(lower) X-ray photographs (X 2): top left, hollow seed; bottom left, shriveled embryo and storage tissue; **right**, both with distinct embryo and dense storage tissue of sound seed.

90. The Tennessee research deals with experimental plantings made by the Tennessee Valley Authority 25 years ago. Volumes at the current stage of development confirm the superiority of pure shortleaf pine over yellow-poplar. The mixed plantings of these two fine timber species are intermediate in volume.

91. Sweetgum, as one of our outstanding hardwood species, makes a worthy subject of research on juvenile variation at North Carolina. Controlled nursery production of some 500 seedlings from each of 30 selected seed trees has provided the prescribed stock for the out-planting tests, and also physiological evaluation.

92. The development of nursery production of optimum planting stock of sweetgum, yellow-poplar, and sycamore is the subject of a new study at Alabama.

Timber Stand Improvement

93. This research deals with the problem of inadequate movement of herbicides and poor kill for control of **undesirable** woody plants in Oklahoma. It featured adding ammonium thiocyanate to the 2,4,5-T. The simultaneous applications enhanced both upward and downward translocation in winged elm, but not in blackjack oak. This indicates the possibility of better top-kill of winged elm by aerial spraying with ammonium thiocyanate added to the 2,4,5-T.

Specialty Products

94. The New Hampshire project represents one of two significant research efforts in New England on cultural practices to improve the quality of balsam fir Christmas trees in planted and natural stands. From the three results on this project it currently appears quite promising to grow good-quality balsam fir Christmas trees for which demand far exceeds supply. Tentative inferences on final analyses scheduled for next spring are listed in the following.

(a) Slowing leader growth by basal pruning and tip pruning in the fall is effective; however, neither root pruning nor chemical growth inhibitors are recommended.

(b) Possible correlation between application of complete fertilizer and development of internodal buds indicates that the tree could fill out from internodal branches. This could make unnecessary the slowing



Christmas-tree research (Kansas State University, Statement 96).

Fig. 10-(above) Typical Kansas family examines many trees before the final purchase.

Fig. 11-(below) Plantation of Scotch and Virginia pine that yields premium grade Christmas trees. Corrective shearing helps make low-grade trees saleable.



down of leader growth -- thereby shortening the time required to grow a good-quality Christmas tree.

(c) Fertilization with nitrogen and complete fertilizers have improved tree color consistently.

(d) Clipping of lateral tips improves the tree density markedly.

95. The Vermont project currently reports on balsam fir planted for Christmas trees. Response to two-ounce application of a balanced slow-release fertilizer includes improved growth, needle length, bud formation and foliage color. Chemical herbicides completely removed weed competition around trees. Less desirable is mowing that only aids in finding the trees, and plastic mulching that is expensive and also proves detrimental to balsam fir. Seeds have been collected from 28 selected trees, some involving controlled pollination, in five geographic areas to examine tree variation. Plantings of balsam fir seedlings from two known seed sources were made and cultural improvement practices were begun in natural stands, with extension to the extreme northern part of the producing region. Intensive cultural practices of thinning, pruning, shearing, and fertilizing in natural fir and spruce stands show promise of early production of high quality trees.

96. Current results of research are released to Christmas-tree plantation operators to provide guide lines for culture and management under Kansas conditions. The inclusion of different coniferous species and hybrids in blocks

in the plantings to test adaptability has shown several advantages. There is less risk of losing a complete plantation due to fire, disease, or insect infestation. There is greater ease and economy management, including shearing, spraying, grading, and ultimate harvesting. Trees harvested from research plantings were well received on the Kansas market. Kansas-grown Christmas trees commanded good prices at both the wholesale and retail level -- in several locations selling better than imported trees (See Figure 10). The premium and Number 1 trees from harvested blocks ran as high as 87 percent. This is well above the general market level of 50 to 60 percent. Only 3 percent of all trees harvested graded utility or cull. Applications of several colorants to correct color deficiencies were tested in varying concentrations and at different dates. Some of these appear to have a place in upgrading certain strains of pine. During the 1966 shearing season, attention concentrated on developing methods of corrective shearing on lower grade trees in order to upgrade them for increased profits (See Figure 11).

97. A 6-acre Christmas-tree plantation of 10 coniferous species was established by L.S.U. in March, 1966 at the Southeast Louisiana Experiment Station. A needle-retention test on three Christmas tree species revealed that an Arizona cypress retains color and freshness when its base is continually covered with water, and absorbs as much as one pint of water per day under conditions typical of Christmas-tree display. In another test, needle retention of trees of 5 species placed in wet sand was compared to that of an unwatered tree. Scotch pine surpassed other species tested in color and needle retention, whether potted or unpotted. Douglas-fir was second, followed by Arizona cypress, Virginia pine and shortleaf pine.

98. In the University of Georgia project on physiology and biosynthesis of oleoresin in slash pine, new methods and techniques of tapping trees for gum have been tested. Three of these hold considerable promise for reducing cost of production by prolonged flow and a concomitant reduction in frequency of visits to individual trees. Techniques for purifying and studying the various components of oleoresin from living trees progress toward determination of the biochemical pathways of production in living cells. This involves degradation (by chemical techniques) of resin acids in crude gum in order to locate tagged carbon atoms in tracing the pathway of production. Advances in knowledge include the lateral and vertical movement of gum within the tree following chipping: the potential amount of gum extractable during the first 72-hour period following wounding; the amount of gum produced by synthesis and sustained flow thereafter; and basic information on exudation pressures as influenced by environment and different heights in the tree.

99. The research on essential oils from wood and foliage of 5 pinyon-juniper species in Utah is progressing. Four species yielded significantly more oil during the winter months than at other seasons. The fifth species, Utah juniper yielded the greatest amount of oil during the spring months. These patterns closely repeated themselves over the two-year collection period. Leaf oil extraction from slash that was several weeks old proved lower in quantity and different in chemical properties compared with extractions from fresh foliage. Analyses continue on the color, viscosity, specific gravity, and seasonal variations in properties of these essential oils.

Special Plantings

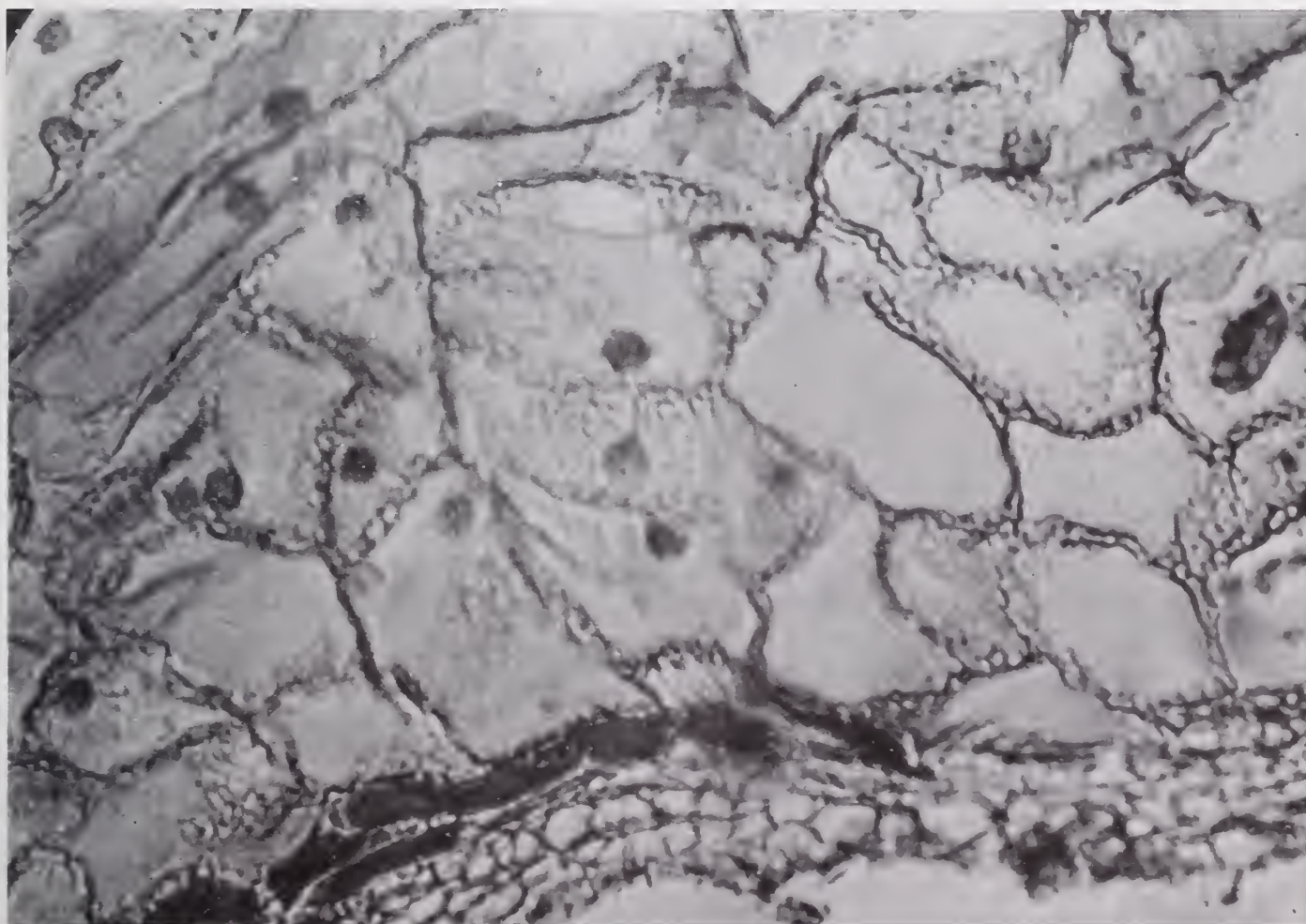
100. The Kansas project on shelterbelt and windbarrier influences concentrated on the collection of soils data during 1966. Contact with landowners provided data on original planting, initial cultivation, and later management. The resultant information clarified incomplete data concerning spacing, design, and species selection on specific sites.

101. The measurement of windbreak influence on microclimate and plant response is the objective of the project at the University of Nebraska. Protection by windbreak increased the crop of sugar beets but not the total production of sugar. In spring 1966, six windbreak systems were planted on a 600 acre tract of land at the field laboratory at Mead. Each consisted of over a mile of 2-row shelterbelts. In all, some 200 acres of land will be sheltered to varying degrees as the trees grow. Wheat is planted to provide a measure of site uniformity and productivity under non-sheltered conditions. Installations are completed for research on evapotranspiration in conjunction with windbreak influences.

102. The South Dakota project seeks techniques to improve the moisture regime of dry sites for establishment and growth of plantations. In the Big Bend area the plots chemically fallowed in 1965 for planting to conifers received prescribed treatments: furrowing prior to planting, both for planting in the furrow, and in undisturbed fallowed strips; also herbicide application after planting. Initial soil moisture was good under all treatments. First year survival of plantings of eastern redcedar proved excellent in all treatments, though injury from dalapon was noted. Ponderosa pine survival was low, which is attributed to poor stock. A micro-watershed was constructed on a Pierre clay site. The soil was ridged between the rows and covered with black plastic leaving exposed a one-foot band in the row to collect runoff. Moisture probe tubes were installed to measure moisture gain in the row. At Brookings, a corrugated plastic greenhouse was constructed. Raised beds were filled with Pierre clay topsoil from the Big Bend area where eastern redcedar and ponderosa pine will be planted to study minimal moisture levels for survival on these tight soils.

103. The project on shelterbelts in North Dakota includes current research on factors that favor the development of pine root mycorrhizae in alkaline soils. Ponderosa pine from the Towner, North Dakota Nursery, inoculated with Montana forest soil made an average annual growth of 11.1 inches. Three of 86 isolates collected from the nursery proved to be mycorrhizae formers by pure culture techniques. One of these isolates has been identified as Cenococcum grandiforme, (Sow.) Ferd. & Winge. Histological studies showed that Navashin's, Bouin's, or Zirkle's fixatives would effectively fix mycorrhizal roots. Dehydration was accomplished with tertiary butyl alcohol. The roots were embedded in 61 degree Tissue-mat and sectioned at 10 microns. The best of several stains examined was 0.1 percent Thionin differentiated with Orange II saturated in ethyl alcohol. Stained sections revealed a well developed mantle and "Hartig net" (See Figure 12). Sections fixed in Zirkle's fixative, which retains the cytoplasm, show apparently well-developed intracellular hyphae.

Fig. 12- Photo-microscopic evidence of mycorrhizal infection of ponderosa pine root - a longitudinal section showing mantle of fungal strands, or hyphae, (at bottom) and the "Hartig net" of hyphae which have penetrated between the walls of adjacent cells throughout most of the tissue shown. (North Dakota State University of Agriculture and Applied Science, Statement 103).



Completion of a survey of insects of shelterbelts in eastern North Dakota provides data on insect species, tree species, tree age, percent of belts infested, and extent of damage--invaluable for locating problems or intensive research. No extensive insect-caused mortality of trees has appeared; however, generally damage increases with age of trees. Defoliation, the most common damage ranged from 23 percent on American elm to 85 percent on green ash--with the fall cankerworm the most abundant and cosmopolitan defoliator. A sampling of multiple-row shelterbelts showed that up to 35 years of age the overstory keeps the understory vegetation suppressed with roots concentrated in the upper foot of soil. The weight of roots, largely grasses and forbs, averaged low, except where the canopy cover was opened by loss of crowns. Of 14 pre-emergence chemicals tested at rates of 2 and 3 pounds of active chemical per acre on trees and shrubs, only simazine, Caporal, and Herban 80 W's and Caporal 5 G gave satisfactory weed control with no injury to newly planted seedlings. None of the 14 controlled germination of sweet clover; none affected survival of seedlings planted one year after spraying; and none showed detrimental build-up from successive applications. Amitrole T at 2 gallons of commodity per acre excelled at 90 percent control of leafy spurge 11 months after treatment.

104. A Kansas study deals with spoil bank revegetation .

105. A North Carolina study of the taxonomic distinctness of Carolina Shagbark Hickory finds its distribution overlaps that of the "true shagbark hickory". Collections of specimens of both taxa have been made in the Carolinas, Tennessee, and Georgia for leaves, branches, and fruits; also, soil samples. Mature wood has been macerated and drawings made of vessels. Leaves have been cleared, stained, and mounted for vein studies. In absence of data, tests were made that showed 120-day stratification at 32-34°F gave adequate germination of Carolina shagbark seed.

106. This Delaware study is on the influence of light and nutrients on growth and fruiting of holly. To compare native American holly and the clonal cultivar Miss Helen planted under stands of mixed hardwoods, loblolly pine, and in an orchard, experimental trees were tagged and diameters measured. To provide a foliar diagnosis technique a series of samplings were made of leaf number, position, age, and season of collection from cultivars and native hollies given differential nitrogenous fertilizers; after analyzing the leaf samples for N, P, K, Ca, Mg, Fe, Cu, Mn, and Zn content, the leaf collection procedure will be determined.

Forest Protection

The urgency of research on forest protection grows with the intensification of forest management and recognition of the enhanced values of trees and forest land. Reduction of the risk of loss, and better definition of probabilities of loss are the common goals of this research. Scientists of diverse specialization are enlisted in solution of problems of forest protection. Their project reports grouped under the following subjects of Fire, Pathology, and Entomology cover the progress in research on forest protection except for items on animal damage which are grouped under Wildlife.

Fire

107. A University of California project deals with vegetation and fuel hazards on wildland watersheds. Pattern diversity, or the "mixed-ness" of species, was studied in seven stands and five vegetation types: grassland, woodland-grass (savanna), sagebrush, chamise chaparral, and mixed conifer forest. This year, the pattern diversity method stressed is in terms of bits of information, H . Highest values for H occurred in grassland and savanna; lowest values, in chamise chaparral. Distinguishing types by pattern-diversity had ecological interest and gave significant positive correlations with productivity, total plant mass, and apparent stability. However, it does not give meaningful correlation with fuel conditions. For example, on grasslands where ten annual species may occur on a square foot, the H is very high, and all species have similar kindling points, ignitability, and caloric values. In contrast, chamise in almost pure stands has a very low H , and its caloric value and potential heat output far exceeds grass stands. Presently, attention is focused on a fuel-pattern-diversity measure that would group species by distinctive fuel characteristics to provide a meaningful measure of relating vegetation distribution to fuel hazards.

108. This project in the Department of Forestry, Louisiana Polytechnic Institute deals with comparing a plot of longleaf pine with an unburned plot.

109. The use and effects of prescribed burning after timber harvesting in the northern Rocky Mountains is the subject of a project in Montana. The completion of the "fuel measurement component" of the prescribed burning tests occurred during 1966. The fuel measurements made before burning and again after burning provide information on what the forest manager can expect in the way of site preparation from a fire that burns known amounts of fuel. By a relatively simple sampling scheme, fuels can be measured and the effect of fires can be predicted.

Pathology

Forest pathology is one of the fields in which the large number of urgent research problems continues to demand far more research time than a limited corps of workers can devote. Losses in volume growth and damage to tree form in some important instances impose serious limitations on the management of otherwise desirable tree species. Very detailed knowledge of a disease is often necessary before real progress toward control by non-chemical means can be made. The spectrum of concern of the forest pathologist, moreover, extends all the way from diseases that attack seedlings to those which must be guarded against during the period between harvesting and the production of the finished wood or wood-based product. Graduate students in forest pathology receiving training through their participation in McIntire-Stennis projects will find many opportunities for employment on research programs with many challenging problems worthy of their best efforts. The following progress statements on projects in pathology provide good examples of challenging problems.

110. The project on ecology of forest tree diseases and wood deterioration at North Carolina State University at Raleigh reports on diverse phases of research. Genes for improving resistance to fusiform rust were shown to exist in loblolly pine in a form that can provide gains in this trait. Results from control-and open-pollinated crosses showed variation in susceptibility to be under genetic control which is stable under varied environs. Also susceptibility was favored by high soil fertility.

To study wood use in residential construction, a random selection of 32 houses was examined. Joists in half the houses contained some decay; those in new homes contained up to 140 percent moisture -- in one case remaining above the fiber saturation point for 5 months. All 32 houses had some molds on joints, sills, and subflooring. Joists in houses with basements and forced air-heating systems contained less moisture and less decay than houses with crawl spaces and heat-pump systems. Soil covering with polyethylene reduced relative humidity and moisture content of joists. Altogether, 114 fungi were isolated from the under-structure of these houses.

111. Studies in Massachusetts on the sugar maple decline continue. The typical symptoms of affected trees of extensive interveinal and marginal scorch of leaves, premature defoliation and dieback, occur in drought years on marginal sites under conditions of high stress for water, as in compacted or shallow soils (See Figures 13 and 14). The microclimates of these declining trees is characterized by higher rates of air flow and evapotranspiration, higher temperature and bulk density of the soil, and by lower humidity and soil moisture as compared with normal forest trees. Scholander bomb tests disclosed a far higher tension for water in the vascular tissues of declining than in normal



Sugar maple decline study (University of Massachusetts, Statement 111).

Fig.13. (above) Typical tree with branch dieback and thin reddish-colored leaves.

Fig. 14- Typical leaf symptoms of declining tree in Fig.13.



Fig.15- Leaf symptoms (cf Fig.14) of seedlings from withholding water.



forest trees. Repeated applications of water in drought periods to large declining field trees over a two-year period arrested decline or achieved recovery. Typical decline symptoms of leaves was induced in potted maple seedling from which water was withheld until the leaf blades drooped (See Figure 15). Thus, water deficiency appears a primary causal factor in sugar maple decline. In another phase of the research, nitrogen fertilization of trees in an area with severe maple decline symptoms has resulted in dramatic improvement in leaf color and nitrogen content. Other fertilizers had little or no effect. Results of soil analysis seem to indicate that soils low in both nitrogen and calcium have trees of lower vigor and greater incidence of decline symptoms.

So far, attempts have failed to identify the causal agents of sugar maple decline with viruses, or high chloride content. Mechanical, seedling, and vegetative transmissions have thus far been negative. Similarly, there is no direct evidence of a primary role of insects. The artificial defoliation of trees and branches started in 1964 provides indications: defoliation near June 1 caused more mortality than that near August 1; high branch mortality followed defoliation; and re-foliation was slower for defoliated trees in the shade than those in the sun. Many of the symptoms of sugar maple decline can be produced by inoculation of maples with plant-parasitic nematodes. Dagger nematodes extracted from soil in areas of maple decline when placed around the roots of maple seedlings produced root symptoms identical to those observed in greenhouse and forest. Numerous bacteria isolated from unhealthy sugar maple trees, including some resembling those causing the "wetwood" disease of elm, are now undergoing the protracted growth studies required for identification of a bacterial species. Bacteria are also being inoculated into trees of various species of maple growing either with a normal water supply, or under drought tent treatment.

112. In a Pennsylvania study designed to determine the environmental conditions and tree interactions of sugar maple trees conducive to their attack by the fungus Fusarium solani. Controlled freezing of the base of living sugar maples in the Spring prior to bud break, resulted in several small cankers on two of twelve trees tested. These test results support reports that sudden changes in bark temperature can create localized ruptures in the living tissues that provide entry for fungus spores. Collection of sap yields from size-matched pairs of cankered and uncankered sugar maples indicated that yield was significantly less from cankered trees. Sampling of tree bark and soils in maple stands, for the presence of Fusarium solani has yielded many isolates that are now being tested for pathogenicity by inoculation into wood, cambium, and bark tissue of healthy trees.



Fig. 16- More than 10,000 cuttings of Port Orford cedar are being rooted to test individual resistance of 525 parent trees to root rot disease. (Oregon State University, Statement 113).

113. Resistance to Phytophthora root rot of Port Orford Cedar is being sought through research at Oregon State University. A screening process, utilizing levels of apparent field resistance, has been set up under greenhouse conditions. Over 10,000 cuttings representing 525 clones from Port Orford cedar trees are being rooted for resistance testing in mist propagation facilities of the project (See Figure 16). Seven Phytophthora isolates of diverse origin are being tested for pathogenicity and subsequent use as inoculum.

114. This University of Hawaii project reports that the subject fungus Phytophthora cinnamomi survives in tropical forest soil as chlamydospores. These resting structures germinate directly by means of germ tubes within 4 hours on selective agar media.

Here colonies can be readily

identified. Survival of the chlamydospores in soil is regulated by moisture and temperature; sensitivity of the fungus to dehydration makes this pathogen less adaptable to survival under drought conditions. To study survival and population fluctuations of chlamydospores, a soil sieving technique has been developed that separates these resting structures ranging from 50 to 140 microns which are collected in the 53-and 38-micron screens. Following isolation chlamydospores are plated for germination counts.

115. In the continuing research at the University of Wisconsin on the oak wilt disease, electron and polarized light microscopy have disclosed the following significant findings: Fungus spores inside xylem vessels soon after inoculation, plugging of vascular elements by tyloses and gums preceding foliage wilt, fungus hyphae both within and between cells and even within cell walls and tyloses as wilt develops, and, localized necrosis of cells at one end of the abscission layer in the leaf petiole just before premature activation of this layer leads to early defoliation. Red oaks die rapidly. In contrast, many white oaks persist with the fungus confined by thick-walled fibers, gum-filled xylem parenchyma, and noninfected ray parenchyma. Trunk injections with TCPA through cones or Manget capsules have delayed initial foliage wilt and also

have arrested further symptom development in branch-inoculated, susceptible red oaks. Of over 2000 northern red oaks collected, 180 seedlings have withstood trunk inoculations. Continued testing of soil injections confirms the effectiveness of control for oak wilt and vascular wilt diseases like Dutch elm and Verticillium.

116. Research underway at the University of Arkansas has added substantially to our knowledge of nuclear behavior in fungi that attack trees. Use of an array of radiobiological, histological, and histochemical techniques on the oak wilt fungus Ceratocystis fagacearum established the operation of an unusual form of nuclear migration. Further investigations with Fomes annosus and other important fungi show that the centriole structure is actively involved in nuclear movement at the cellular level. This is the first notation of the role of a nucleus in other than the division process. It creates opportunity to more fully understand certain mechanisms at the cellular and molecular level of fungi destructive to forest trees.

117. A University of Washington study deals with the origin and extent of the occurrence of Fomes annosus butt-rot in young stands of western hemlock under intensive management. Preliminary observations indicated the presence of Fomes annosus in natural stands of western hemlock. One case was in stumps of 10-year old trees one year following pre-commercial thinning; the second case in 30-40 year-old trees previous to the first commercial thinning operation in southwest Washington. Origin of the initial infection is being studied. Evidence is critically needed on the risk of damage by Fomes annosus resulting from intensive management of young-growth stands of western hemlock -- the highest-yielding timber species in the Northwest.

118. The project on Fomes annosus root-and butt-rot of Pinus echinata in Missouri reports the following results: Data collected at monthly intervals on levels of Fomes annosus airborne and foliage trapped inoculum and infection of freshly cut pine stumps showed marked seasonal differences. All reached a peak in the winter months, then a June to August seasonal low -- though with stump infection rates as high as 10 percent. Of three stump protectants applied 1 to 3 days after felling, urea gave the most consistent protection, though none provided absolute control. Studies on the extent of bole invasion by the fungus indicate that it is present continuously to 4 foot height in dead and 3 feet in living shortleaf pine. Nutrition studies showed that the fungus can utilize a wide variety of carbohydrates as sources of carbon, which indicates the organism's complex enzyme system.

119. A project at the University of California deals with the epidemiology of Fomes annosus, a root rot of worldwide importance. In California beyond its threat to ponderosa pine a series of tests of the

fungus indicated colonization of stumps of redwood and Douglas-fir constitutes a threat. Spore dissemination studies established that dispersal occurred throughout most of the year, representing a continuing threat of disease spread.

120. The project at the University of California on the wetwood of the native firs concentrated on the wet heartwood of white fir. The wet zone was found of general occurrence, and corresponding to the heartwood zone of the log. None of the microorganisms isolated was suspect as a pathogen.

121. In the study of diseases of quaking aspen in Wyoming, examination of 48 groves showed general distribution of leaf spot and defoliation; 8 groves had a substantial percentage of decadent aspen trees; and in 4 groves Fomes conks were observed.

122. The project on ecology of wood decay at the University of Minnesota, reports on inoculation trials with Fomes igniarius, the heart rot fungus of aspen trees. Fresh wounds are necessary for germination of the basidiospores obtained from conks on living trees. Thus the heart rot organism first becomes established in the sapwood of a living tree. Significant also is the finding that some organisms present in the host tissues can inhibit, and others stimulate, basidiospore germination.

123. The University of Minnesota study reports fire necessary to control dwarfmistletoe in Arceutholium pusillum, black spruce. In stands where control has been attempted by removing all living trees, the infection on reproduction sampled 1.5 percent after 6 years. Trials with the oil and burn technique in infected stands left no living black spruce and no dwarfmistletoe surviving to be present in reproduction. Dwarfmistletoe seed dispersal in 1966 occurred from September 10 to 25, extending out to 18 feet, and the fall beneath infected trees averaged 0.54 seeds per square foot. After seed dispersal an additional 10 percent were collected, which had dislodged from branches.

124. The Washington State University study of Hypoxyylon fuscum found that the fungus becomes established in the wood of northwestern alders rapidly decaying all cell types. Later, hyphae emerge from the wood and ramify throughout the bark. Then, stromata (pillow-shaped masses of fungal tissue) form beneath the bark periderm, rupturing it, and produce flask-shaped fruiting bodies (perithecia) bearing mature ascospores that undoubtedly spread the organism to other alder trees.

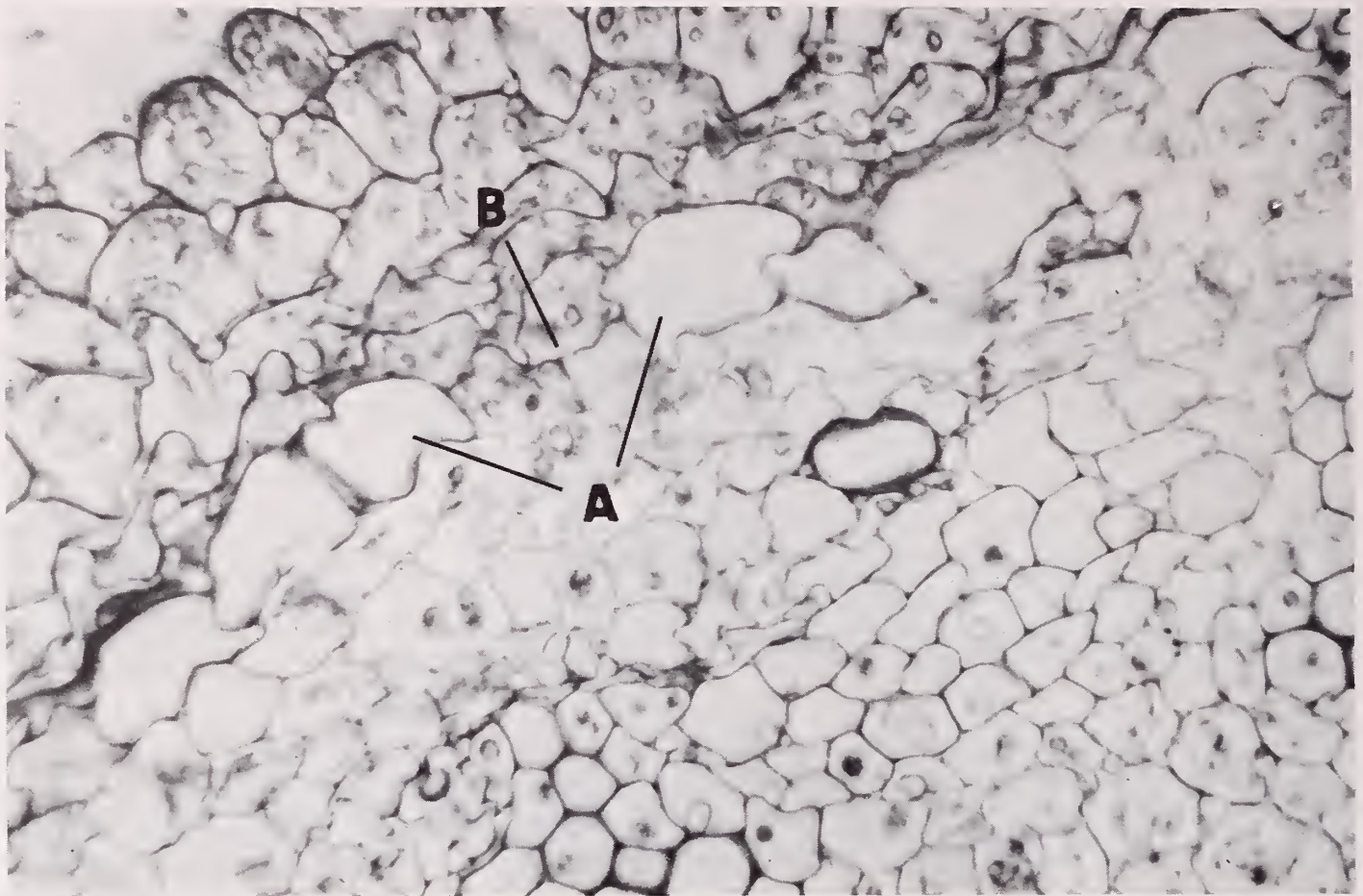


Fig. 17- Cross section of inoculated 15-day-old root of Virginia pine showing: A. resistant suberized endodermal cells, and B. mycelium of Pythium debaryanum penetrating non-suberized endodermal cells. 560 X (University of Maryland, Statement 125).

125. The University of Maryland project on forest tree seedlings and soil fungi focused research on the mycosis of Virginia pine. The fungus Pythium debaryanum infecting the pine roots is recognized as one primary cause of damping-off loss of newly germinated seedlings. Virginia pine seedlings were removed from soil at 8 intervals from 15 to 180 days after germination. Their roots were inoculated in cultures of Pythium debaryanum and after 36 hours were examined histologically. Colonization with mycelia of roots 15 to 25 days old was general except some suberized (corky) endodermal or lignified vascular cells (See Figure 17). In roots 25 to 70 days old the amount of mycelium decreased with the increased barrier of suberized endodermis. Roots older than 70 days with fully developed endodermis were generally not infected. Any methods to speed endodermal suberization should lessen susceptibility to damping-off.

126. Scientists in Oklahoma are studying the effect of mycorrhizae on the initial development of seeded shortleaf pine on major soils. Results in the 4-million-acre area of Cross Timbers in east-central Oklahoma

indicate that only soils like the Linker, Hartsells and better sites of the Hector-Pottsville group may be biologically suited for conversion to shortleaf pine. The high fidelity of plant grouping on these sites suggests that post-blackjack oak, oak-hickory or better plant associations serve as indicators. Soil tests of pH, mineral, nitrogen, and organic matter content could not be directly related to seedling development of shortleaf pine. The differential development of shortleaf pine seedling grades suggests response to incidence of mycorrhizae. Mycorrhizae appear of sufficient frequency under certain native plant groups west of the commercial pine-hardwood boundary to provide adequate inoculation of direct-seeded pine.

127. This project at the New York State College of Agriculture at Cornell University deals with the effects of ectotrophic mycorrhizae on tree growth. When Monterey pine and sudan grass grew together in fumigated soil, the pine grew better with mycorrhizal inoculation or heavy phosphating. Grass, however, grew less in presence of inoculated pine.

128. A study of pine-oak gall rusts is reported underway by the Department of Forestry, Louisiana Polytechnic Institute.

129. In the study of oak decline disease in Texas, the demonstrated causal fungus Cephalosporium was found to invade only woody tissue, and it is suspected of producing a toxin which kills oak trees.

130. The project on forest tree diseases in Puerto Rico reported continued observations on decline of West Indian mahogany. This disease evidenced by blight and yellowing of leaves was noted on mature trees, as well as on saplings. Four fungi isolated from blighted mahogany leaves proved negative in pathogenicity trials.

131. The biology of fungal pathogens associated with littleleaf and seedling diseases of southern pines is the subject of a new study at Auburn University.

132. Studies are underway at the University of Arizona on life histories of many fungi pathogenic to forest vegetation. Telial collections of important rust fungi are being utilized in inoculation studies to clarify alternate host relationships. Isolations of several parasites of rusts and needle-attacking fungi are being studied for potential biological controls. Collections of specimens of diseased plants from both range and watershed areas are expanding the Phytopathological Herbarium of the Arizona Agricultural Experiment Station.

Entomology

Studies on tree insect problems were largely on biologies and life histories. Cone and seed pests received considerable attention. Ecological and biological control studies were continued at a number of institutions.

133. More than 50 species of insects were found associated with loblolly and shortleaf pine cones in Arkansas. Of these cone moths, of three Dioryctria species, appear to be most damaging.

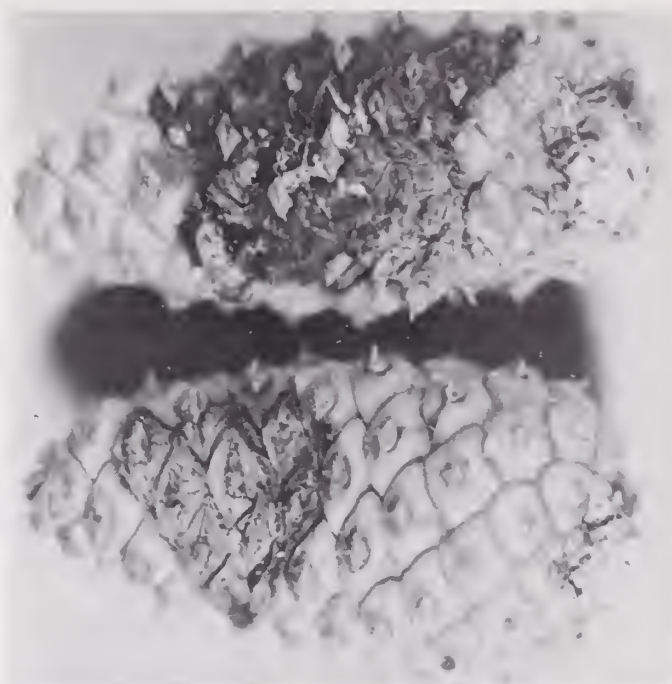
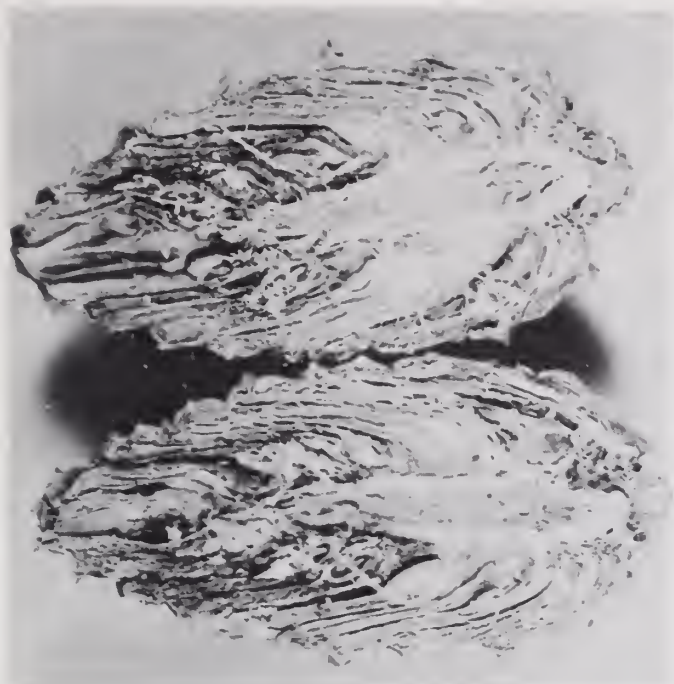
134. This Arkansas project reports that Ceratocystis ips was the only blue stain fungus consistently found associated with Ips grandicollis. This bark beetle in the presence or absence of its associated blue stain fungus was unable to attack weakened loblolly pine trees, 4-6" in diameter, even though the oleoresin exudation pressure was reduced to zero.

135. In an Arkansas project progress was made toward breaking the diapause of the pine sawfly, Neodiprion taedae linearis, by exposing the cocoon to varying photoperiods. Several thousand larvae sprayed with the virus obtained in 1965 resulted in 100% mortality. Identification of parasites of the sawfly, continues.

136. The Texas project reports that two semi-artificial diets have shown promise as rearing media for the southern pine beetle. An egg procurement technique has been perfected in the laboratory. It permits rapid, efficient egg collection from the natural host material.

137. In the Oklahoma project several systemic insecticides applied for control of the Nantucket pine tip moth provided protection, but of short duration. Granular formulations applied to the soil gave longer periods of protection but were slower in action. Some phytotoxic effects were noted.

138. A study in Georgia deals with important insect species damaging cones and seeds carefully sampled on shortleaf, loblolly, and Virginia pines. At least three species of flies of the family Cecidomyiidae damage cones of shortleaf and loblolly pines (See Figures 18 and 19). Several parasites and other insects are under study, but have not yet been identified. To date three species of coneworms have been identified.



Shortleaf pine cone damaged by fly (*Cecidomyiidae*). Fig. 18-(left) Cone section with damaged seed, Fig. 19-(right) Whole cone damage. (George Foster Peabody School of Forestry, University of Georgia. Statement 138).

139. In the study of cone insects of loblolly pine in Maryland, the life history of the cone worm (*Dioryctria ametella*) showed no clear-cut broods or population peaks in the state. Experiments with systemics to protect cones were inconclusive.

140. In the Puerto Rico project on arboreal termites, host trees of *Nasutitermes costalis* now number 142, while *N. nigriceps* number 102. Surveys made in the Virgin and other Caribbean Islands confirm the hypothesis that *nigriceps* is a dry area species, while *costalis* prefers humid areas. Tests for control of both species of termite by spraying with Aldrin, Dieldrin, Chlordane, or Heptachlor show some promise.

141. In Puerto Rico chemical treatments of a sudden outbreak of the cedar shoot-borer, using Endrin and Disyston failed to provide control. It is believed that treatment timing is critical. Green fruits of cedar are being selected to develop further information on infestation cycles. Apparently the pest has two cycles per year.

142. The University of Vermont project provided comparative growth measurements from weeviled and unweeviled white pine totalling 225 trees in three northwestern counties. Data are in process of analysis.

143. In the New Hampshire project the task of identifying mites and springtails from forest soil samples is underway. Over 220 species of oribatid mites and over 40 species of springtails have been found thus far. Densities have ranged from 21 to 250 individual per cubic inch of soil. These findings will be related to soil physical properties, white pine site quality and growth.

144. In a Maine project, areas susceptible to significant pine leaf aphid damage were identified with areas having a lower site index for pine and relatively large volumes of spruce, their primary host, in addition to pine the secondary host. Areas of lower susceptibility have less spruce in relation to pine present. Within regions of aphid abundance, damage appears most prevalent in stands on sandy and gravelly soils.

145. The Michigan State University study of the predaceous ant Formica obscuripes and its potential use as a biological control agent has provided data on the nests, food habits, activity, foraging range, distribution, and density. Direct observations have indicated that it will attack various larva, leafhoppers and other potentially injurious pests of jack pine and Scotch pine.

146. At the University of Michigan pilot work on stridulatory sounds produced by four species of Agrilus beetles was undertaken as a phase of the courtship behavior studies. Significant results were obtained on sexual recognition by males. Considerable taxonomic work was necessary to develop information on the phylogenetic relationships of the beetles.

147. In the Ohio project preliminary surveys of pests of pine established a new record for the aphid Eulachnus agilis attacking pine. Infestations may cause premature needle drop. Under a newly assigned leader this project will deal with host-parasite-predator relationships of insects and mite pests of Christmas trees.

148. In the Wisconsin project on population dynamics of sawflies, the first generation larvae of the sawfly Neodiprion rugifrons did not feed on current year foliage of jack pine. Second generation larvae preferred the new foliage. Two sawfly generations can cause complete defoliation of jack pine in one season.

149. In a Kansas project the complete life history was determined of a tortricid moth, a pest of junipers in shelterbelts and windbreaks. The larvae were found to feed when exposed to temperatures ranging from

50°F to 95°F. In the fall they mine within the foliage where they pass the winter in the fourth larval instar. Some feeding takes place in the spring, followed by pupation and adult emergence during late June and early July. Following mating and egg-laying, eggs hatch in about 10 days.

150. The Montana project on spruce budworm defoliation in the Rocky Mountains reports field work complete.

151. In an Idaho project the introduction of a systemic insecticide, methyl demeton, into trunks of Douglas-fir by means of "Manget Tree-Injector Units" was proved feasible. Significant reductions were obtained in insect-caused seed losses in open-growing, pole-size trees. Seed losses from all causes in treated trees averaged 20 percent of losses in untreated trees. Two grams of insecticide per diameter inch was used; one gram gave inconsistent results.

152. In the University of Washington project olfactory stimuli were found to influence motor responses of the Douglas-fir beetle. The fresh bark of Douglas-fir exerts a positive response, fresh needles a negative response, and 1-year old bark no response. The motor response may be to the volatile organic matter emitted by the tree; i.e. the terpenes.

153. The New Mexico project reports on cone insects. The cone beetle destroyed 99 percent of the already poor ponderosa pine crops on Lincoln National Forest in 1965. The spruce budworm destroyed 20 percent of the small Douglas-fir cones in one area. Douglas-fir cones at four sites showed average infestations of cones was 34 percent by the Douglas-fir cone moth, 18 percent fir coneworm, and 2 percent by seed moths (Laspeyresia sp.). Seed moths and the fir coneworm infestations ranged from 2 to 18 percent. Peak emergence of the cone beetle was in early May. In all, damaging insect species numbered 10 identified on ponderosa pine and 6 reared from Douglas-fir. Insects are being reared from 107 samples of cone collections.

Forest Management

Under the broad scope of forest management recognized in the McIntire-Stennis program, this section includes statements on projects in nine groupings ranging from timber management to multiple-use.

Timber Management

154. The Purdue University project on mathematical programming of Central Hardwood forestry in farm planning reported substantial progress. A dynamic linear programming model was prepared to permit concurrent planning of farm and forest activities on a farm consisting of 305 acres of cropland and 40 acres of woodland. The model was evaluated for seven separate periods over 33 years. Inclusion of growth transfer functions between periods was a unique feature of the dynamic model. Growth and sawtimber prices influenced labor resources markedly. Farms with excess labor in early summer and late fall can utilize this profitably in the woodland; however, when labor is limiting and discount rate high, (5 percent or more) withdrawal of labor from farm activities is not profitable.

155. A Michigan State University project is evaluating the financial desirability of various cuttings in stands of mixed hardwoods, second-growth northern hardwoods, and red pine underplantings. Growth of mixed hardwood sawtimber stands for a 10-year period following group selection cutting and two levels of single tree selection cuttings shows increases in value considerably below an interest rate of 5 percent. Heavier cuttings that reduce the basal area of initial growing stock from 122 square feet per acre, to 70 square feet show higher earnings than lighter cuttings that leave 90 square feet. The results lend support for lower levels of residual growing stock in managing mixed hardwoods than those in use in the Lake States. For additional analyses, field data have been collected on timber stand improvement work applied under the ACP program to 30 private second-growth northern hardwood forest stands in the upper part of Michigan's Lower Peninsula, and to liberation cutting to release under-planted red pine from overtopping low-grade hardwoods.

156. This Minnesota project deals with applying computer technology and operations research techniques to problems of inventory in resource analysis and forest management problems. The research has yielded statistically valid methods of combining the results from point samples with plots for estimation of the stand parameters of volume and basal area. This, in combination with the distribution functions developed

for selected forest stands will permit the determination of more efficient designs for sampling by points and plots. The computer programs completed provide the initial stage for future programming and analysis of inventory data.

157. A New Mexico project deals with costs and returns of present forest management practices that could be used by private forest land owners. Thinning is a practical economic solution to the number one problem on privately-owned timber lands in New Mexico, that of an oversupply of small dimension timber. Thinning costs were \$10.98 per acre in 1964, while the returns from the products of thinning were \$14.48. Other management practices are not economically feasible without cost-sharing programs. One characteristic of retail Christmas tree business is the trend toward smaller-size. The small retailers handling fewer than 600 trees per year from 1962 to 1965 increased from 8 to 43 percent of all the retailers. Retailers indicated that white fir is the preferred species, followed by Douglas-fir with third place held by the imported Scotch pine.

158. The study in South Carolina on maximizing returns from even-aged stands has developed a record system for the investment analysis of each timber stand. Each analysis requires stock and stand tables including the product category, the unmerchantable, and the cull trees present. The necessary field inventory of the Clemson Forest is in progress.

159. This project in Tennessee aims to identify determinants of intensity of forest management with levels of income of forest owners. Private, non-industrial forest landowners were scored by the intensity of forest management they practice. They are identified in the following ranked groups: (a) The highest management scores were held by owners who had better educations, higher family incomes, larger forest properties, professional occupations, and who resided away from their forest land. (b) Above average scores went to housewives who had inherited their forest lands, and had high family incomes with many dependents. (c) Below average scores went to older farm owners, with long tenure, better education, and high family incomes. (d) The lowest management scores belonged to owners who had poor attitudes toward land stewardship, long tenures of small-sized forest holdings, low levels of education and family income, and poor health. Farm ownership grouping brought out considerable variation of interest. The non-farm owner's intensity of forest management was better explained by level of family income than size of his forest land holding. The present condition and stocking of his land appears more important, and the non-farm owner may find the investment approach to forestry more promising than do farm owners whose goal is the maximizing of current net income.

160. A project activated in Georgia relates cash flow and forest management policy to income and property taxes. Major revisions accomplished that introduce various tax structures into the original Forestry Operations Simulator programs are being tested for accuracy. Also, a meeting held with 13 industrial tax representatives to get their opinion on the proposed approach to the problem elicited comments and suggestions that should be of great benefit for the future direction of the project.

161. Development of linear economic models for determination of optimum forest production schedules is the objective of a University of California project. The linear economic models developed last year included risks by incorporating variance and covariance statements in the original risk-less models. However, lack of necessary data for practical applications will be considered in planning subsequent empirical work.

Mensuration

162. This Purdue project deals with the development of growth and yield functions from remeasurement data on permanent plots in predominately uneven-aged stands of mixed species. The quantification of growth and yield in an uneven-aged stand is based upon the number of trees initially above or passing a minimum size class during the growth period. Data from permanent growth plots provided a satisfactory biological basis for an equation describing mortality or change in the initial number of trees in a stand. The combination of ingrowth and mortality equations provides an estimate of the total number of trees present. Equations have been developed to predict growth in basal area and volume. Moreover, prospects appear good for successful application of functions known to characterize biological growth processes for these quantities. The results will provide methodology for incorporating the components into compatible growth and yield models for computer evaluation of uneven-aged stands.

163. The Oklahoma project on tree stem distribution and forest structures, reports completion of the computer program for statistical analysis. This program was designed for obtaining correlation coefficients for some 300 joint frequency tables. The results of the analysis indicate high positive correlation of stem occurrence in closely associated small diameter classes for nearly all forest types of the U. S. studied, and in closely associated larger diameter classes, in most softwood types, especially those referred to as "group-selection" types. The cases showing the highest positive correlations for closely associated diameter classes also show significant negative correlations of stem occurrence in widely dissociated classes.

164. The Oklahoma project evaluating site conditions and frequency and mortality patterns of timber in the Ouachita highlands extended to an additional 260 Continuous Forest Inventory plots.

165. This Mississippi project deals with relating tree and stand variables to stem form of loblolly pine. Bark thickness, as an obvious cause, explained 54 percent of the variation in Girard form class. This ratio of inside-bark diameter at top of the 16-foot butt-log (or scaling point for volume content) to DBH outside bark (the basal measure of trees and stands) has unsurpassed directness. Form class variation with expressions of crown development ranks next to bark; tree-to-tree variability is high. Taperline curves developed for 60 trees remain to be analyzed.

166. This Louisiana State University School of Forestry and Wildlife Management study of a 40-year old slash pine plantation compares the results of four methods of thinning that began at age 13, with each other and with an unthinned control. Results showed that even the lightest of thinning treatments salvaged the potential mortality from competition. Thinning had not affected the average height of the dominant stand. However, thinning methods had resulted in differences in crown development at 40 years. Crown lengths were greater on the thinned plots than on the unthinned plot. Trees on the thinned plots had slightly less taper and were slightly less knotty on the butt log than trees on the unthinned plot. Thinning had no appreciable effect on either the specific gravity of the outermost ten growth rings or the proportion of pole-and-piling trees in the stand.

167. Another L.S.U. study in pine plantations is just getting under way on measurement of competition.

168. Louisiana Tech's follow-up on the H. H. Chapman loblolly plots at Urania included sampling of soil, and increment cores for specific gravity of wood.

169. On the least squares estimation for description of tree growth at North Carolina a computer program has been developed to provide for visual representations of the error surfaces associated with the growth models chosen for study. The program provides data points through which contours can be drawn to describe the shape of the error surface.

170. The Georgia project on prediction of growth and yield got under way with the collection of field data on slash pine plantations.

171. In the project to determine the growth and yield of West Virginia hardwoods, study plots have been established for the yellow-poplar type, and thinned to specified residual density. All plots were surveyed, marked and mapped for permanent record. Where necessary cooperative agreements were obtained from the landowners.

172. This project deals with development of volume tables and tree volume equations for the major forest tree species in Vermont. Taper curves on merchantable portions of sample trees showed an average form class of 81 for all sugar maple in the state, compared with the average of 79 reported for all maple in the Northeast. Form class averaged 82 in the Connecticut and Champlain Valleys, and 79 in the Green Mountains. Volumes were determined by Smalian formula from measurements of 500 sample trees, and variations in several factors affecting tree volume are being examined.

173. A Northern Arizona University project compares different measures of the density of tree cover to see which is best related to the growth of ponderosa pine. With data from 121 samples, analyses have begun to develop stand density expressions for second-growth ponderosa pine. In addition, some preliminary basic relations between stand density and growth have been investigated. The sample stands showed no significant relation between basal area per acre and either 10-year basal area growth or 10-year radial growth; likewise Bole Area showed no relation. Apparently, additional variables such as age, height, and site index must be introduced to improve the correlation. Equations developed using all available variables showed that Tree Area Ratio is a function of Height/Age, Basal Area, (Basal Area x Height)/Age, and Basal Area/Age. A Stand Density Index equation developed for ponderosa pine is: $\log \text{ of number of trees per acre} = 4.3079 - 1.8907 \log \text{ of average stand DBH}$. Crown Width Index in the form of regressions of bole diameter or crown diameter has been found to be affected by age, height, and site index, but not by basal area per acre. Finally, Crown Competition Factor, independent of age or site index for the sample, may prove a satisfactory measure of stand density of ponderosa pine in the Southwest.

174. The Humboldt State College project deals with developing tariff numbers and volume tables for hardwoods in the redwood region. This investigation established the suitability of the tariff system of sampling tanoak stand volume. As a result, local industry now has an accurate system of cruising this potential pulp species, where previous systems were prohibitive in cost. Field work completed on Pacific madrone shows promise of the tariff system for this hardwood.

175. In 1966 this project on ecological basis of forest production involved nutrient gradient determinations in jack pine, red pine, and northern hardwood stands in central Minnesota. Results from soil and plant analyses are assessed by synecological coordinates--the method in systems ecology developed at the School of Forestry. Preliminary analyses show good agreement between light determination by the ozalid method and synecological coordinates. Analyses of material collected earlier in the central Minnesota Pine Section indicated that the actual productivity in extensively managed forest stands may contradict potential productivity. Thus high silt and clay content of soil may detrimentally affect site index while basal area continues to increase substantially. Conversely, low nitrogen content in soils may have little effect on site index; however, low nitrogen content is associated with low basal area of forest stands. In such situations the use of weighted site indexes as measures of actual productivity can provide improved guides for forest management.

Site

176. In the project at the Utah Experiment Station analysis continued on data from Engelmann spruce-subalpine fir plots on the College Forest. Site quality was best expressed as total height at a specific tree diameter. This combined with basal area per acre contributed more than 19 other variables to correlation with periodic annual growth of stands. However, these two variables gave only fair prediction of stand increment per acre.

177. This project deals with growth of swamp and water tupelo in a 100-acre Georgia swamp. Both soil and water sampling was done on 63 plots, each with a water well. Water analyses showed oxygen content ranging from 12 to 23 percent, and carbon dioxide content from 2 to 15 percent. Carbon dioxide content was higher in slow-moving water and near the edge of the swamp. Within the swamp the range in pH was from 3.5 to 5.0. Levels of nutrient concentration varied widely--in parts-per-million, iron was 6 to 1000, zinc 2 to 20, manganese 2 to 148, sodium 6 to 87, magnesium 30 to 248, and calcium 97 to 850. Measurements taken on 750 trees included height, age, and radial growth. Ages ranged from 25 to 180 years and site indexes from 58 to 78 feet. The analyses of samples and data that are still in process suggest that growth and yield of tupelo swamps will be low, regardless of nutrient levels, unless some system of water control is practiced.

178. In the Virginia project on parameters of site for important species, intensive studies of the productivity of Virginia pine continue. Detailed analysis of the growth during the season indicate a photosynthetic efficiency in young Virginia pine stands comparable to agricultural crops in the same locality. Concurrently, the pattern of

utilization of solar energy by Virginia pine is studied in a series of stands ranging in age from 16 to 65 years. Greenhouse studies have compared the seasonal growth, photosynthetic efficiencies and leaf mass of seven hardwood species. Preliminary analysis of resultant data indicates that differences among the species in dry-weight increment are largely due to differences in leaf area, while differences in photosynthetic efficiencies are smaller. On the relation of productivity to site in mixed hardwood forests, published data for 159 temperate, boreal forests have been combined to obtain a regression for estimating stand weight from basal area and height. As new data becomes available, this regression will be tested for utility in estimating dry-matter growth in the mixed hardwood forest.

179. On a new Florida project supplementary data are being gathered for correlation of soil survey information on series, type and phase with site index of southern pine.

180. In the Pennsylvania study of soil-site in northern hardwood species, analyses for field and laboratory measurements of white ash stands are in progress. Preliminary results indicate that a site quality estimator based on the logarithm of the product of basal area and height of the sample trees will be appropriate. Greenhouse studies of seedlings show that ash is less susceptible to damage from flooding or a periodically high water table than black cherry and sugar maple. Analyses are in progress on site requirements for black cherry, white ash, and sugar maple.

Aerial Techniques, Survey

181. This University of California project seeks ways in which imagery obtained from aircraft in several wavelength bands of the electromagnetic spectrum can serve in forestry. During 1966, multispectral remote sensing activities were located in three areas: (a) Geysers in the Coast Range, (b) San Pablo Reservoir near San Francisco Bay, and (c) Blodgett Experimental Forest in the Sierra. Areas (a) and (b) were flown at a scale of 1/12,000 and in part 1/2,000 testing 4 promising film-filter combinations. The identifiability of major tree species on each film-filter combination was carefully determined and ground-checked for accuracy. Results indicated that for mapping tree species through large areas of the Coast Range aerial photography might best employ Ekta Aero Infrared film and a Wratten 12 filter with coverage at two scales: Complete coverage of the entire area at small scale of 1/12,000 to 1/20,000; and, for sample spots of 5% of the area, at a larger scale of 1/2,000 to 1/3,000. Interpretation of tree-species on the large scale photography could be extrapolated to the remainder of the area covered only at the smaller scale. This would be supplemented by limited on-the-ground checking to insure high accuracy standards.

At Blodgett Forest multispectral imagery was obtained, both in June and September at 7 scales ranging from 1/5,000 to 1/30,000, using 2 types of film and filter. The detectability of insect-induced mortality in timber stands was determined for each combination of film, filter, scale, and date of photography. Results indicated that Ekta-Aero Infrared photography effectively detects western pine beetle-killed ponderosa pine even at 1/30,000, the smallest scale tested--moreover, at scales of 1/10,000 or larger haze penetration was good. A separate test at Blodgett Forest using electronic scanning instruments flown by the University of Michigan obtained multiband imagery simultaneously in 22 bands of the electromagnetic spectrum. These included portions of the ultraviolet, visible, near-infrared, and thermal infrared spectral zones. Results show that within the regions of the electromagnetic spectrum that can be sensed directly, photographic emulsions provide better imagery than line-scanning techniques.

182. In the project to develop aerial volume tables for central Oklahoma stream-bottom hardwoods, all data are collected and key punched on plot and tree cards. Cubic volumes for 8-foot lengths have been calculated on some 2,000 trees. Computer design for construction of the volume tables is under way. Tree volumes are tested by species and drainage to distinguish significant classes. Regressions for cubic volume per acre include crown diameter and diameter breast high; total and merchantable height; crown surface area and basal area per acre.

183. In the investigation of sampling designs for forest inventory at Syracuse University a simulated forest has been constructed and stored in the memory of the computer. A technique for cluster sampling has been developed and appropriate computerized statistical tests made on characteristics of the forest and sampling technique. The technique proved appropriate within limits of population parameters defined. The results include three specific computer programs:-Program I calculates the theoretical distribution of trees and derives theoretical tree stand tables. Program II builds a random forest stand in the memory of the computer under several parametric restrictions. Program III builds a simulated forest, samples the forest according to the techniques of cluster sampling, and makes elementary statistical tests on the cluster means.

184. Michigan Technological University is developing standardized programs for automatic data processing of forest measurement records. They constructed tentative systems procedures for processing of industrial Continuous Forest Inventory Cases. Standard formats for the total system comprise 8 segments. Programs are written and operating for 3 segments: I-Tree Detail Error Check; II-Tree Computation; and III-Plot Total Listings and Summaries. The interest is so high that 2 pulp and paper companies already use the 3 segments to compute their timber volumes and growth and summarize sample data by species, growth component, and forest district.

Recreation

The outdoor recreation projects fall into three general groups. The first group on demand for recreation comprises 9 projects concerned with determining the extent and nature of demand for various types of recreation which may be provided in the forest setting. The emphasis in these studies is on the human factors -- who are the people using the available recreation facilities; where do they come from and what are their family and income characteristics. Attention focuses on measuring possible demand for resource facilities with respect to the kind of recreation provided, and distance from population centers and other types and qualities of recreation resources. A second group of 3 projects on appraisal of recreational resources is involved with the inventory and appraisal of resources that appear to have potential use for recreation. Also included is the analysis of the quality and capacity of the resources. Land cover, scenic views, presence or absence of water, climatic factors such as temperature, amount and reliability of snowfall, or even extent of insect infestation all are factors to be evaluated in appraising recreation resources. Problems of managing recreation resources constitute the third group of 6 projects. For privately owned recreation resources the problems revolve around how to manage so as to make a profit on the specialized enterprises having some form of recreation as the chief money making activity. On others it is a question of how to manage recreation activities to not interfere with the main enterprise. For publicly owned recreation facilities the management problems studied are how to use the facilities so as to avoid deterioration of the resource and what intensity of use is most consistent with maintaining the resource for future generations. Also included among these projects are studies of how to preserve both aesthetic and physical aspects of natural phenomena, and how to allocate among users having such different goals as hunting and hiking.

185. Colorado State University is engaged in inventorying present and potential forest recreation areas in three mountain counties. A suitable forest recreation resource evaluation form is being developed. The uniform method of collection and tabulation using a combination of "point" and "zone" inventory techniques has been applied. The information is being keyed to classifications of recreation use recommended by the Bureau of Outdoor Recreation for ready coordination with other recreation inventories.

186. Humboldt State College is making a detailed study of a coastal recreation site forested with second-growth redwood, to evaluate its potential and analyze alternative uses.

187. Another project beginning at Humboldt State College involves determining the reliability, quantity, and quality of snowfall in the Horse Mountain area as a basis for evaluating feasibility of further development of winter recreation facilities in the ski area.

188. This project at Louisiana State University School of Forestry and Conservation is clarifying the role of large private forest ownerships in outdoor recreation in the State. "Big land owners," of 15,000 acres or more, own or control nearly one-half of the private forest land in Louisiana. They provide the bulk of areas used for hunting and fishing by the public. Large owners are tending to further increase their holdings through long term leases, timber cutting contracts, or outright purchase. It appears that they do not intend to expand recreation facilities as rapidly as the anticipated increase in public demand. Land owners are seeking better control of recreational use of their lands, especially when such use interferes with timber production. It is expected that the proportion of these private lands available for recreational use would increase only upon payment of fees of some sort.

189. The University of Tennessee is studying the recreation resources of large private forest tracts in order to determine their recreation potential and provide a basis for solutions to problems involved in the fuller utilization of this potential. In all, there are 96 forest tracts larger than 5,000 acres, with a total area in excess of 2 million acres. A questionnaire has been developed for use in personal interviews with the owners of these large forest holdings.

190. Southern Illinois University is making a survey of the physical and economic characteristics of private horseback riding enterprises in the State through personal interviews of entrepreneurs.

191. Research is continuing in Minnesota on some ecological implications of the management of Itasca State Park. One of the major attractions of this park is the presence of 6,000 acres of virgin red pine, a species which requires fire for successful regeneration. This three-year study of the processes of natural succession and regeneration in what is the largest and most important of Minnesota's parks indicates that the virgin pine forest will almost totally disappear unless effective silvicultural measures can be developed which are acceptable to park visitors and management.

192. Research on the recreational use of forest lands in Montana aims to provide for improved recreational management through better understanding of public desires and needs to be correlated with economic and ecologic considerations.

193. A study at Washington State University provides information on guidelines for recreation in multiple use management of wildland areas. Recreational use of the study area is concentrated in a five-week season of big game hunting. No facilities are provided for campers, and access is limited to four-wheeled drive vehicles on old logging roads. During this season traffic counters have been tested and interviews made with a sample of visitors to estimate hunting use of the area. (Figs. 20, 21)

194. A study at the University of Arizona aims to estimate demand and develop recreational use forecasting models for better evaluation of forest recreation areas. User and resource characteristics will be combined into a classification scheme. Initially in the Graham Mountain recreation area, auto-camper families have been interviewed to determine socio-economic characteristics.

195. An Idaho study is progressing on developing and evaluating methods for estimating recreation visits and use in unattended wildland recreation areas. Instruments developed have been tested extensively and compared with visual observations and interviewing of visitors to recreational study areas.

196. A study of forest recreation investment opportunities focuses attention on outdoor recreation activities and preferences of Iowa residents. The results will provide comparisons with the BOR's 1965 national survey and also furnish additional data on at home outdoor recreation. Activity preferences, development cost, and anticipated use rates have been combined into a model which should help local recreation boards, public agencies, and even private interests choose among outdoor recreation development possibilities.

197. The Louisiana State University School of Forestry and Wildlife Management has studied the effect of State forests and parks on public recreational use of private forests. Results show that except for parks located along a through highway most summer users are local or in-State residents. The State parks support a heavy use during peak periods of their highly-developed areas and facilities -- which represent only a small part of total available acreage.

198. The University of Maryland has continued its analysis of the status of private forest recreation development in Garrett County. Identification of non-resident property ownerships totalled 1402 on upland sites and 1140 along Deep Creek Lake. The total of persons involved is estimated at about one-third of the total permanent population of the County. The socio-economic characteristics, values and expectations of the non-resident owners differed substantially with location of their property. Thus the upland property owners show more



Wildland recreation study (Washington State University, Statement 193).
Fig. 20-(above) Typical elk hunters' camp at high elevation.
Fig. 21-(below) Battery-operated traffic counter installation enclosed
in polyethylene with brush cover removed.



interest in hunting and camping, whereas, those along Deep Creek seek more recreation provided by commercial enterprises, such as, movies and summer theater. In general, all non-residents enjoyed the physical, social, and recreational attributes of the area, but were not satisfied with the current public and private services.

199. The New York State College of Agriculture at Cornell University has initiated a study of the suburban forest. The objective is to determine what the suburban forest owners expect from their woodlands and reactions to the harvesting of forest products and the applications of certain management practices. A questionnaire interview of a sampling of owners in the Elmira-Corning urban complex will be conducted to learn their own objectives and reactions to examples of woodland practices.

200. The Utah research continues on developing regression analyses for predicting both amounts and patterns of recreational use based on the number of vehicles in a closed recreational complex such as Logan Canyon.

201. Another Utah study has been developing a prediction model for public use of a potential campground complex on the basis of its location relative to the distribution of the population and character of potential users, size of campground, and the competing facilities. Findings to date are in line with evidence from previous studies that use of some recreation facilities can be predicted. However, the relevant variables in predicting fishing use of a stream, differ from predicting use of a particular camping complex, and may vary even for different kinds of campgrounds. It is considered critical that prediction equations be restricted to the specific activity for which they were developed; moreover, it may be risky to apply them over wide geographic areas.

202. During the past year the University of Washington study on the relation of recreational uses of forest lands to their management for timber production has emphasized recreation user characteristics. The characteristics of users of easy access and remote recreational resources in **National Parks and National Forests** are being compared. A questionnaire has been prepared to sample the attitudes and characteristics of a population of 5,000 recreationists. The analysis will center on the relationship of user attitudes and characteristics to recreation management policy.

Wildlife

Public interest in wildlife is increasing. The availability of leisure time has led to a broader appreciation of the aesthetic and recreational value of our wildlife resources. This is being reflected in a greater emphasis on research in this area. There is a dearth of information on the biology, behavior and management of birds, fish and mammals. Research aimed at realizing maximum benefits from our forest and range-land deals with complementary utilization by people, domestic animals, and wildlife.

203. Of three studies concerned with the relationship between browsing and forest regeneration, the New York study at Syracuse University determined deer population densities by drives. Two drives of 305 acres and 255 acres gave counts of 10 deer and 16 deer, respectively. Forest vegetation conditions were measured by a series of plots, which showed regeneration to be inadequate (See Figure 22). Prevailing high populations were reduced by public hunting. Re-analysis of vegetative plots following this reduction will document the relief from browsing achieved.

204. In Virginia, the second deer browse study is concerned with analysis of sourwood leaf material throughout the year. White tailed deer are known to ingest not only green leaf material but fallen leaves during late fall and early winter. Little is known of normal nutritive levels in leaves and less of the value of dead leaves. A homogenous stand of sourwood following a controlled burn was used as the source of analytical material. Leaves collected from June 1965 through January 1966 were analyzed for: protein, crude fiber, ether extract, nitrogen free-extract, ash, iron, copper, manganese, sodium, potassium, phosphorus, and calcium. Significantly, there was a steady decline in protein levels until November, then an increase. Crude fiber, increased slowly until leaf fall then increased rapidly as did calcium and iron. Nitrogen free-extract decreased after leaf fall as did ash, manganese, phosphorus, and potassium. There was a steady increase in gross energy values; however, values were the same for December and January. Leaves are high in minerals, but have a lower fiber content than twig material, therefore leaves may be more palatable than twigs. This may explain why deer ingest leaf material for some time after it has fallen from the plant. These results give some insight into the seasonal changes which occur in the nutritive elements of an important deer food plant.

205. Research by Humboldt State College has revealed that the Roosevelt elk also has an adverse effect on forest regeneration, condition of prairie areas and associated vegetation types. Seventeen point transects were used to determine range production on the beach area. Utilization was also determined for the over-used area. Elk use has

resulted in browsing and damage to conifers and hardwood timber. In the grass areas heavy use resulted in a downward trend of invasion by poor quality forbs and grasses and a decrease in desirable perennial grasses. Results of 1966 indicate there were too many animal units on the area. The 1966 herd was approximately half the size of the 1965 herd as a result of transplanting.

206. In a study to determine the patterns of movement of whitetail deer in Rhode Island initial work has concentrated on deer capture and the development of techniques to facilitate capture. A device for automatically collaring deer on their runways with transmitter collars appears feasible and with improvement of the collar's locking arrangement should permit the collaring of deer with transmitters without handling the animal. Standard deer live traps have been employed with success during the fall, and live-trapping operations are continuing. Tracking operations in progress involve the use of RDF receivers and antennae to determine the mobility and activity of the marked animals.



Fig. 22- Luxuriant forest regeneration on left of fence is lacking on the right, which is subjected to browsing by high animal population. (State University College of Forestry at Syracuse University, Statement 203).

207. Research in New Mexico is providing valuable information on mule deer management. The development of livestock water and two big game catchment units has resulted in both a better distribution and an increase in deer on the Ft. Stanton Range. The summer population which previously was far less than the surrounding area is now 14 percent higher. The hunter kill during the last hunt was up 5 percent over the previous year, and the fawn production was 25 percent greater than recorded in the past. Studies on the use of the range in relation to water have been intensified as new permanent waters have been developed. Five additional transects have been installed bringing the total number of sample plots up to 475 which are read semi-annually to determine seasonal use. The data indicate decreasing use of the range as the deer move to distances greater than two miles from water. The findings suggest a close relation between water availability and deer distribution and production, and that the conversion of a no-use area into one of commercial livestock use has improved the habitat for deer.

208. A study at the Storrs Agricultural Experiment Station in Connecticut on the prenatal sex ratios and the productivity of the white-tailed deer is nearing completion. Reproductive data for 8,564 white-tailed deer have been assembled from twenty eastern states, reduced to a single format, and employed to determine statistically the influence of physiography, forest types, soil types, and land uses upon the fertility rates (embryos per dam) of eight yearly age classes. Forest type and soil type were found to exert the greatest influence upon deer fertility. Accordingly, the eastern United States was classified according to six major "fertility regions," based upon forest-soil classifications. These fertility regions may prove useful to forest biologists to manage deer on interstate bases, or with some further refinement to manage herds within a state.

209. Research at Michigan State University is getting underway on the ecology of four woody plants with aesthetic and wildlife food value, namely: pincherry, downy serviceberry, hawthorns, and staghorn sumac. The environmental factors limiting their survival and growth on wildlands are being determined.

210. Under a project at Idaho on computer analysis and simulation of big game population dynamics, major progress has been made in describing needs, collecting techniques, and in programming of segments of the system. Several programs have been prepared for estimating population, rates of increase, and evaluating trends of game kill from food locker reports.

211. Studies in Georgia deal with rabbit populations in Piedmont woodland environments with no game management except curtailed hunting, and on a ~~maximum~~ management of a heavily stocked area under rabbit-proof fence. The stocked area showed range overuse, increased external parasite burdens, and very little or no reproduction. This area has been compared with woodlands nearby. Rabbits have been collected to **deter-**mine the normal breeding picture. All rabbits have been checked for tularemia agglutinens. There is no evidence of recovery or immunity in the population. Predator interrelationships have been studied.

212. Scientists at Storrs Agricultural Experiment Station are also interested in rabbit population development in Connecticut, but from a different standpoint. They are determining relationships among different species in the same area. Their trapping on one major study area and 6 minor study areas has yielded 50 captured specimens that are identified in the field, marked, and released. Certain habitat data, **pertinent** to species behavior in each season, have been collected.

213. A Minnesota study deals with evaluating the effect of small mammals on seed and reproduction of mature red pine stands. Installations involve two areas, gridded with 200 seed trays and 200 exclosures to check seed survival during winter. Live trapping on the study areas and kill trapping nearby indicated the abundance of five species of small mammals.
214. A Louisianan study deals with the influence of the eastern woodrat in the hardwood forest. In addition to feeding trials of penned woodrats scientists conducted censuses during 1966 which indicated a relationship between woodrat population and density of understory and forest type of overstory.
215. In the area of research on management of game birds and fish populations, a study has been initiated in Massachusetts on food and shelter requirements of the ruffed grouse.
216. Research in Georgia directed toward increasing quail harvest is developing useful data. Populations around the year have been determined on square-mile study areas--two in the Coastal Plain, and two in the Piedmont. Intensive studies included trapping and dyeing the birds. An evaluation of using artificial feeders in the Piedmont area indicated they have little practical value under these conditions. This was surprising since quail food is scarce in Piedmont mixed pine-hardwood forests. The area in the Coastal Plain is on lands which are rapidly being converted from farms to woodlands. Quail are still abundant but adult-young age ratios indicate the beginning of a population decline.
217. A related study of the bobwhite quail is being initiated in Tennessee. Two areas totalling 4,230 acres have been categorized according to land use or cover type. Fifty-three coveys have been located and research initiated on food habits and effects of management practices on population development.
218. A Vermont study of the nesting habits of wood ducks is yielding useful information. Nesting in natural cavities of trees located on two major breeding areas in the Champlain Valley was approximately 1/8th as frequent as when artificial nesting boxes were used. Nesting was 16 times more successful in the artificial structures than in natural cavities. This difference resulted from mink and raccoon predation on nests in tree cavities whereas such losses were prevented at artificial nesting boxes by protective metal shielding. Natural cavities for nesting in cut-over bottomland hardwoods are limited. Only 54 cavities occurred in twenty-five acres of marsh woodland in trees 9-inches and larger. Natural cavities occurred principally in cottonwood and soft maples. Nine hundred wood ducks were captured and

banded to implement the investigation of population fluctuation following a fall hunting season and subsequent recovery in the spring breeding season. This included 89 females nesting in one area; 422 day-old ducklings were tagged for determining mortality rates, homing, and fidelity to specific areas in subsequent years.

219. The project at Storrs Agricultural Experiment Station on measuring the effects of fluctuating oxygen levels on growth of brook trout reports that results to date reveal fish exposed to fluctuating oxygen levels grow at a reduced rate.

220. A Georgia study designed to determine the effects of radioisotopes on wildlife was set up this past year although some preliminary work had been done previously. Around 300 specimens of wildlife, mostly game animals such as rabbits, deer, and foxes have been "counted" in a whole body counter constructed for this purpose. Excellent progress has been made in determining the biological half life of cesium-137 in an omnivore-predator, the gray fox. Indications are that this isotope is rapidly eliminated in wildlife if the animal is put on a cesium-137 free diet. Elimination is considerably more rapid than has been reported for man.

221. Research scientists in Maine are measuring the influence of a known population of deer upon vegetation. Pre-release vegetation tallies and deer exclosures have been completed at Outer Heron Island. The release of deer has been scheduled for December. This will help to avoid molestation of the deer by hunters. The details of the vegetation studies are being analyzed with the aid of a computer. A study emphasized the relationship between a large deer population and an over-utilized food supply has been completed. Strip censuses, drive counts, and aerial counts were employed to determine the estimated population of 250 deer on the 6,575 acre island. The island was cover typed with the aid of aerial photographs. The overstory and understory vegetation was characterized on the basis of 1080 sample plots. Only 7 pounds of preferred deer browse per acre was available. Non-preferred and low palatability browse composed 96 percent of the 1,334 pounds per acre of available browse. Thus the heavy deer population of 1 deer per 25 acres has caused serious habitat deterioration. Phase II of a 4-part long-range plan for deer research is in progress at Isle Au Haut. Census methods are being tested and evaluated. To date 23 deer have been live-trapped, measured, tagged and released.

Range

222. The nature of sites where western juniper (Juniperus occidentalis) is climax have been distinguished from newly invaded sites in an Idaho study (See Figures 23 and 24). The old juniper stands are located on elevated positions such as ridges and escarpments. The soils are usually shallow to bedrock, rocky or gravelly, low in cation exchange capacity, and high in base ion exchange, especially calcium. Rock outcrops are common. "Invasion" stands occupy sites on valley slopes and bottoms where soils are deeper, less rocky, higher in cation exchange capacity, and lower in base ion exchange. Vegetation differences are also striking. Climax stands have a crown cover of juniper averaging 47 percent, and contain trees as old as 400 years or more. Understory vegetation is relatively sparse and patchy, with a shrub foliage cover of only one percent. Invasion sites have an open crown cover averaging 20 percent and no junipers are over 100 years in age. The understory is better developed with a shrub foliage cover averaging 14 percent and a much higher frequency of herbaceous species. The climax sites have a lower potential for plant productivity, but have more scenic and recreational value. Recently invaded sites are inherently more productive of forage, and this constitutes their main commercial value. Control of juniper should be confined to the invasion stands.

Western juniper sites studied. (University of Idaho, Statement 222).

Fig. 23- Climax stand of old trees with patchy understory on rocky soil.



Fig. 24- Young "invasion" stand in sagebrush-grass vegetation.



223. Forested lands provide an important source of summer forage for livestock in the mountain west where ranches often are adjacent to forest land. A Montana study reveals definite patterns of utilization by grazing livestock. Stream bottoms dominated by Kentucky bluegrass or redtop are utilized first. Cattle then move to abandoned roadways, openings in the timber, or ridgetops where bluegrass and clover occur. Later grazing utilizes less palatable grasses, sedges, and browse plants growing in the open, and these plants growing in the shade are utilized last.

224. This Wyoming project analyses the plant-animal-soil-climate relationships of the juniper and limber pine zones. A new classification was established to categorize Utah juniper and Rocky Mountain juniper trees by four maturity classes on the basis of height, diameter, and aspect. This study reveals that Utah juniper can be controlled by a twice-over helicopter application of Tordon at 2 pounds per acre in 10 gallons of water. Mechanical clearing of juniper trees was followed by a marked invasion of shrubs, forbs, and grasses. Winterfat planted in the clearing in 1965 has proven adapted to the site and to early utilization by game.

225. A Wyoming study on encroachment by lodgepole and limber pine focused on germination and seedling survival. Added water and reduced competition were found to enhance germination and survival of conifer seedlings; whereas, additional water plus shading reduced the survival.

226. In New Mexico studies of range site characteristics confirmed the predictable fact that cover and production were higher on loamy upland sites than on stony hill sites. Ranches operated in conjunction with farming activities where feed was produced proved more economic than those with no farming units. Grazing studies indicated intensity of utilization decreased as distance from water increased.

227. Differences between ponderosa pine trees growing along natural park borders and in adjacent forest areas were studied at Northern Arizona University. For trees averaging 11-inch DBH the basal area per acre in the forest was more than double that on the border. Growth characteristics were similar during early years but after 40 years the "slenderness ratio" (height divided by diameter breast high) for border trees dropped below 3 while for forest trees the ratio remained above 3. For the same DBH, the border trees were shorter, and possessed more branches, and leaf area 50 percent greater than forest trees. Of numerous environmental factors measured, only light intensity differed notably. The percent of sunlight from June to August for border trees was more than double that for the forest trees.

228. In the Black Hills of South Dakota considerable instability exists in forest-grassland transition zones. Ponderosa pine is increasing at the expense of the little bluestem grassland. Several different soils in the grassland park areas are associated with ponderosa pine invasion. Morphological soil differences may have resulted from the influence of grassland on the original grey wooded soils developed primarily under forest. Possibly many grassland park areas that once had been forested will revert to climax vegetation of forest in the absence of disturbances such as fire.

229. A newly initiated Utah project will study the effects of intensity and season of clipping foliage of native range plants (simulated grazing) on the soil moisture regime.

Watershed

230. This Colorado project deals with assessing water quality at varying regimes of natural flow and land use conditions ranging from limited development to non-use. Water quality data from ten sub watersheds within a 105 square mile mountain catchment quantifies the occurrence of commonly-used pollution-indicating organisms under near-natural conditions. Further, the numbers of these organisms associated with grazing impact on such streams are given. This information should be of value in determining quality standards of source area waters. In relatively undisturbed watersheds the occurrence of coliform, fecal coliform, and fecal streptococci indicates that all come from the same source. Strong evidence points to cattle as the principal source of these organisms on some mountain streams. Results further indicate that both coliforms and fecal streptococci originate from non-fecal as well as fecal sources. Among the three groups, the fecal coliform group was the most sensitive indicator of pollution by cattle; the fecal streptococcus was the least sensitive. Ratios, such as fecal coliform/fecal streptococci showed no advantage over single organisms in identifying pollution sources. All three bacteria groups increased drastically coincident with spring runoff and storm peak "flushings" in two years; also "post flush" lulls in bacteria concentrations were followed by a rise in late summer counts.

231. This Utah project aims to determine effective means for reducing water use by trembling aspen and Gambel oak and to measure the degree of reduction under various cutting and poisoning treatments. Data on 1966 seasonal changes in soil moisture under different treatments are undergoing computer analysis. An attempt will be made to separate out the deep percolation fraction of soil moisture change. Soils have been analyzed and neutron meter soil moisture data will be analyzed to

determine moisture-holding characteristics of the soil profile at each treatment plot. Collateral analyses will include climatic and meteorologic data obtained inside and at canopy level in each stand.

232. The Washington State project on the interception of snow has established the feasibility of measuring snow catch of coniferous trees by weighing. For continuous weighing a strain gauge system is being developed for use this year to replace the transducer design that proved unsatisfactory. Until automated continuous recording systems have been developed the amount of useful data obtained will be limited. The snow season of 1965-66 was deficient in both number of storms and amount of snow. However, data accumulated during 1966 indicate that lodgepole pine is ten times as effective in catching snow as the deciduous western larch of comparable size. For a moderate storm, Christmas Day 1965, the snow catch amounted to a 0.25 inch depth, and 0.05 inch of water **over that** within the projected crown area. Lodgepole pine showed increased snow catch with increased storm size, whereas western larch showed no relationship. Analysis of data is continuing on other climatic conditions and tree characteristics which are related to catch.

233. On the Humboldt State College study of relationships of natural cover, stream flow, **and soil moisture** data collection is operational on new installations in the Elder Creek watershed.

234. A project at the Agricultural Experiment Station of the Pennsylvania State University deals with determining the influence of forest cover and timber harvesting methods on streamflow. To facilitate the extension of research results from forested experimental watersheds to areas of watershed management, the study of streamflow characteristics of small watersheds in the Northeast was continued. Average annual runoff and daily mean discharges at selected flow durations of 137 watersheds in the Northeast were related to selected climatic, topographic, and land-use variables. Results indicated that the most influential variables on annual and seasonal discharges were precipitation, percentage of watershed area in forest cover, elevation, latitude, July mean maximum temperature, and percentage of watershed area in swamp. Prediction equations were developed for estimating water yield from ungaged watersheds in the 7 major physiographic units in the Northeast. A detailed investigation of the soil mantle on Leading Ridge Watershed Two was conducted by the shallow seismic refraction method to determine soil volume, water storage characteristics, relationships to groundwater table and bedrock. Results obtained will be used to interpret subsurface water flow and backflow contribution to streamflow. A comparison of streamflow characteristics was also made between the 3 Leading Ridge watersheds, which represent the sharply-folded erosive-resistant sandstone ridge areas, and the 3 Shale Hills watersheds, which

represent the lower-lying erosive shale areas of the Ridge and Valley Province. Results indicated significant differences in both water yield and stream timing.

235. This project deals with determination of soil moisture use by pine and hardwood stands on different types of soils and with various stand densities in Massachusetts. Stemflow patterns for white pine, red oak, and white oak were determined in relation to tree size and storm intensity. Graphs were prepared from which stemflow could be estimated for species, diameter, and storm size. Soil moisture studies indicate greater consumption of water by forest stands than by grass cover, although grass dried the surface soil more rapidly. Hardwood stands lagged behind pine stands in water use in the early spring so that they provided opportunity for increased run-off at that time. Hardwood and pine stands used moisture at similar rates later in the growing season. Soil under hardwood stands resaturated sooner in the fall than that under pine stands. Differences in soil moisture use and extraction patterns at different soil depths were evident for pine and hardwood on various sites.

236. To determine and evaluate evapotranspiration losses from several cover types occurring on similar and unlike soils and on various aspects is the goal of this Rhode Island project. This year marked development of a method of access tube installation which permitted the placement of access tubes to depths of up to 5 feet in soils where previously described methods were found impractical. The effective method employed a portable aluminum tripod with a 130-pound weight to drive 1.625-inch, o.d., steel access tubes into which a section of 1.5-inch diameter mechanical tubing with a 0.625-inch core was inserted. The mechanical tubing was screwed to a solid steel point--previously welded to the end of the access tube--with a screw inserted through the core of the mechanical tubing. Access tube installations were made in five forest stands. Changes in soil moisture content have been monitored weekly or biweekly since mid-May from all access tubes. Emphasis was placed upon obtaining information on the mixed oak type; data were obtained from a stand on outwash soil on level terrain, a south slope on glacial till, and a north slope on glacial till. Also, data were obtained from a mixed oak-white pine stand and a pure white pine stand--both occurring on outwash soils on level terrain.

Multiple-Use

237. The Nevada project on the recreational use of isolated forest and rangeland is well-launched since approval in September 1966. A questionnaire that had already been in preparation was taken to the study area to coincide with opening of hunting season in mid-September. To

date over 300 personal interviews have been obtained mostly in areas that are 30 to 50 miles remote from a paved road. Initiation of this study coincided with one of the worst droughts to hit Nevada in some time. Use of the area by livestock has created direct competition for available forage and water. Early returns reflect hunter concern over deer, sagehen and chukkar populations, especially where severe overgrazing of limited winter deer range is evident. Over 85 percent of persons interviewed expressed a strong desire to keep this area in primitive condition.

238. This project deals with evaluating forest resource multiple uses in Montana. The resource classification scheme was established; resource data gathered, and computer processing of the data is underway. Cost data have been obtained for development of recreational use alternatives, and are being collected for timber and range use alternatives.

239. An Arkansas project deals with alternative uses of upland hardwood sites in the Ozarks. In the range development phase, three lots were treated with herbicides to destroy woody vegetation. One lot was given no further treatments and two were seeded to tall fescue, one being fertilized annually with 20 pounds of P_2O_5 per acre. Vegetation density has increased markedly as a result of seeding tall fescue. The introduced species accounts for about two thirds of the vegetation present. Fertilization with phosphorus has increased density only slightly. Vegetation increase in the unseeded plot has been rather limited and primarily consists of Panicums, Andropogon virginicus, and Muhlenbergia species. Upon initiation of utilization by grazing animals, these results should provide guides on pressures the grazing resource can sustain. In other phases of the project, the forestry plots' 5 year examination is not due. The conversion plots show excellent kill of overstory hardwoods from a metered injector and 2,4-D undiluted amine; however, understory kill with a mistblower was only fair. On the 6 small watersheds, runoff and precipitation records are accumulating. Also, pertinent economic and sociologic data were collected.

240. This Purdue project on optimizing outdoor recreation or alternative enterprises in southern Indiana concentrated on planning, methodology, and collection of data in 1966. Mail questionnaires and personal interviews obtained information on the "demanders" of recreation. Public and private providers of recreation were also canvased. Operators, private and state cooperated in sampling their clientele for desired information. Data processing was completed, and demographic and economic information were collected on the 19 counties being studied.

241. The Pennsylvania wildland multiple-use project concentrated on the Quehanna 50,000-acre wilderness and research area. Hunter use of the area during the 1966 small game season was higher than in 1965 or 1964.

242. The New Jersey project on evaluation of multiple uses of public forest land resources has made a study of camping, hunting and fishing on the 12,500-acre Stokes State Forest. A first inventory was completed that included an intensive timber, site and growth inventory based on 360 point-sample plots. Both data coded on IBM cards for computer analysis, and forest cover mapped on a grid system are ready for computer analysis.

243. This project on optimum development of Rhode Island forest land examined what social and economic characteristics of land owners affect their use of land for production of forest products. A profile of the active forest manager reveals that he is typically married, 45 to 54 years old, and has teenage children in the household. He has cooperated in government programs relating to forestry and is aware of the problems facing forest managers. He feels he could do more with his land than he does at present and has sought advice on forest land management. The passive manager is likely to be over 60 years old and a widow or a widower. He has not been involved in forestry related programs and is not interested in forest management problems. He does not feel that he could do more with **his** land and has not sought advice on forest land management. Of the forest land owners in the eleven Rhode Island towns in the study area 36 were passive managers while 20 were classed as active managers.

244. This Vermont project deals with the economics of multiple use of forested land. A scenery classification system has been developed and defined. This system can be used in designating scenic corridors and highways, and in planning scenic highways and scenic overlooks. It provides an objective basis of zoning for scenic purposes that has been used to analyze visual access to scenic vistas.

Forest Utilization

The work of research and the play of ingenuity are evidenced in the progress of wood utilization in the McIntire-Stennis program. Some studies contribute to the urgent need for increased efficiency of production of well-established wood products. Other studies aim at opening up new uses of wood in the economy of the nation. Throughout, projects on a wide diversity of subjects manifest good orientation and good coordination. Their progress statements are presented in the following groups: Logging, Wood Properties, Manufacture, Seasoning, and Pulp.

Logging

245. In this logging cost study the results on rubber-tired skidders were amplified by analyzing the economics of additional operations in South Carolina. Some of the past findings facilitated by this project proved useful in a two-week short course. Participants were 19 professional employees selected by pulp and paper industries. The course was held in July and August of 1966 at Clemson University, co-sponsored by the American Pulpwood Association.

246. Research in logging systems for harvesting thinnings in second-growth Douglas-fir stands is the subject of a newly launched project at the University of Washington.

Wood Properties

The forestry enterprise depends heavily upon wood properties. Wood has unique properties which give it advantages in the market over other raw materials. It also has some properties which are disadvantageous, but whose effects can be minimized or changed through research. Wood properties can be changed, not only through a remarkable variety of processing modifications, but also during growth by manipulation of both tree heredity and the circumstances of the tree's growth environment. And the evolution of tree species in the United States has had so much to do with wood properties, that there is wide room for choice between one and another in searching for properties appropriate to any given use. All in all, wood properties offer a diverse and essential field for research that has concentrated a significant segment of the forest scientists that work in the McIntire-Stennis program. It is important to know what properties of wood are significant and how they vary in magnitude with location and time. Currently two projects are addressed to measurement of variation of wood properties from one part of the tree to another.

247. A project at the University of Mississippi reports on shrinkage and specific gravity in loblolly pine. The number of rings per inch, specific gravity and shrinkage in all directions except longitudinal decreased with increasing height in the tree. Longitudinal shrinkage increased with height, neither specific gravity nor any of the shrinkages varied with distance from the pith; however, the number of rings per inch did increase with distance outward. Thus, radial growth rate had no practical influence on the specific gravity of this species' wood.

248. In a second Mississippi project, patterns of specific gravity variation with height and age were established for black willow growing in the Mississippi Delta. For this species specific gravity either increased or remained fairly constant with increasing height in the tree. At the lower sampling heights, specific gravity initially increased with the number of rings from the pith, levelled off, and then decreased in rings approaching the cambium. This pattern changed with increasing tree heights until at the upper sampling points, specific gravity was highest near the pith and decreased with ring number from the pith.

The variation occurring in wood properties in relation to growth rate, geographic and environmental factors is also of interest both industrially and scientifically. These interests are commonly combined in the same study. In three projects the topic of interest is how environmental differences may affect the properties of wood formed during growth.

249. At Northern Arizona University sampling by 63 plots in northern Arizona and New Mexico of 100-year old ponderosa pine produced 447 increment cores which have been evaluated for specific gravity, percent of extractives, rate of growth, and percent of latewood. The average specific gravity before extraction was 0.42; the average specific gravity of the same cores after extraction with alcohol-benzene was 0.37. This information may be used in estimating the actual wood substance in this type of ponderosa pine as well as probable yields of resinous by-products in kraft pulping. Of the characteristics measured, only those which related to the tree itself, such as percent of latewood and extractives, and none of those related to environment or stand gave significant relationships with specific gravity. Only tree characteristics appeared to influence the yield of extractives; however, precipitation and temperature data were not generally available for analysis of environmental influences. In addition, approximately 18,000 individual fiber-length measurements were made on five second-growth ponderosa pine trees. Samples were taken every five rings out from the pith at five-foot height intervals. There was a high correlation of fiber length with both radius and number of rings from the pith. For one tree, the correlation coefficient between

earlywood fiber length and number of rings from the pith was 0.940, and the corresponding correlation for latewood fiber length was 0.862. It appeared that a good predictive equation could be developed for fiber length in trees less than 50 years old. Since fiber length is a most important element influencing the qualities of kraft paper, these results should be helpful in evaluating ponderosa pine as pulpwood.

250. At Texas a second study deals with the silvical requirements for optimum development of loblolly pine. This stresses specific gravity, fiber length and tree grade of loblolly pine. Records taken at each plot include weather data and stem increments of all sample trees. Also completed is determination of the wood specific gravity for all the sample trees, and wood cores are stored for fiber length determinations. Soil samples collected from each sample tree microsite in three plots were analyzed for sand, silt, and clay content to relate to wood properties.

251. At Maine, in a third study, the specific gravity of red pine in 25-year-old plantations averaged 0.322, and, after an initial drop at the 8-foot level, increased with height in the tree. This contrasts with cited specific gravity of forest-grown red pine averaging 0.391, and decreasing with height in the tree.

252. In a group of projects having a main focus of natural variation in wood properties over areas of some extent, the study at North Carolina deals with tupelo gum variation in specific gravity and fiber length. Significant variation in both characteristics was found between stands, between trees within a stand, and within the individual trees. Data from four stands sampled in the Coastal Plain from North Carolina to Georgia showed between-stand differences in mean specific gravity were small, if the low-density butt-swell region is excluded. Between-tree variation in specific gravity is of greater magnitude than between-stand, while within-tree variation is still larger. Within the individual stem specific gravity showed little change in the merchantable bole above the butt-swell. Horizontally, lowest specific gravity occurs in the first ten rings from the pith after which it remains more or less constant. Fiber length variation is much greater within the tree than between trees or stands. Within the individual tree, fiber length decreased with height about 0.1 millimeter from lower portions of the bole to upper bole. Fiber length increased between the 15th and 30th ring, but no appreciable change was apparent between the 30th and 50th ring. Finally, no relationship was found to exist between fiber length and specific gravity, nor between these two characteristics and overall growth rate.

253. The University of West Virginia study on properties of hardwoods shows interest in black cherry which as old-growth produces an esteemed cabinet-wood. Now wood supply comes from young second-growth trees. In order to characterize the present-day product and establish the range of variation which exists as a basis for tree improvement studies, specific gravity was studied in 50 cherry trees ranging in age from 25 to 50 years. The specific gravity at breast height ranged between 0.54 and 0.65 and averaged 0.58. These values considerably exceed specific gravity reported for old-growth black cherry trees. The predominant pattern of variation in specific gravity along a radius was low from the center outward, then highest at 11 to 30 years from the pith, and again low outside this. Also of interest are 26 hybrid poplar clones of unusual rates of growth. Evaluation as a source of pulp showed the length of fibers ranged from 1.06 to 1.30 mm and averaged only 1.18 compared with 1.32 mm for native poplars.

254. A study of the deposition of arabinogalactan in larch wood conducted at the State University College of Forestry at Syracuse University reports results as follows: Because of the commercial importance of larch arabinogalactan, its molecular weight has been determined by various methods, and its chain-length distribution by gel permeation, using three species of larch. Conflicting data in the literature could be explained when it was discovered that the molecular weight of the arabinogalactan decreased continuously from the sapwood-heartwood boundary towards the pith, that is, with increasing age of the wood. A concomitant increase in the acidity of the wood, caused by liberation of acetic acid from acetyl groups, indicated that the degradation was caused by acid hydrolysis. The arabinogalactan also became modified chemically. This appears to be the first time a wood polysaccharide has been shown to undergo changes in chemical and molecular properties within the living tree. The results are of significance in connection with quality control in the industrial recovery of larch arabinogalactan. The constitution and location of arabinogalactan in tamarack has been found to be similar to that present in western larch.

255. Under study at Montana is the variability of western larch wood in relation to growth, quality, and use potential. Work is in progress on (a) methods of removing extractives from large pieces of wood, (b) equilibrium moisture content of wood in relation to content of extractives, and (c) the strength - specific gravity correlation with extraction of wood.

256. At Oklahoma the last in the group of projects on territorial variation explores the wood properties of shortleaf pine in eastern Oklahoma. Determinations are completed on specific gravity, extractive content, and summerwood percent. The punch card analyses await completion of measurement of length of tracheids in wood samples.

257. The project at Georgia is one of three intensive studies of specific environmental or growth effects upon wood properties. This deals with the variation in stem growth and specific gravity at different stem heights before and after thinning planted slash and loblolly pine. Data on biennial basal area increment and specific gravity were obtained from cores extracted at 7 heights from 2 to 30 feet at 12 years after thinning to 90 square-foot residual basal area in seven loblolly and slash pine plantations of 1933 to 1940. In these thinned pine stands, the percentages of basal area increment and specific gravity had sharply declined prior to thinning, after which they rapidly increased for about 6 years, and then declined again during the last 4 years. In all stands, the basal area increment increased with stem height, while the specific gravity decreased with stem height. Basal area increment at breast-height also increased with an increase in diameter class.

258. The second study in Massachusetts relates certain physical and mechanical wood properties of plantation-grown red pines to quality of site and growth rate. Results reported are based on 16 trees 45 years old from four sites, the ASTM standard mechanical tests of static bending, compression parallel-to-grain, cleavage, and toughness showed mean strength values of 9/10 to half of published values for red pine. In general, the combined effect of growth rate, percent summerwood, and specific gravity on mechanical properties was greater than the individual effects. Radial, tangential and likewise shrinkage values ran 80 percent of published values for red pine.

259. In the third intensive study at Syracuse on effects on red pine tracheid length of potash addition to potash depleted soils failed to show statistical differentiation.

260. A project in Georgia--one of three on anatomical specialties--aims to relate meristematic activity of shoot and needle elongation in the crown of loblolly pine to tracheid characteristics of wood formation in the bole. To create a moisture differential between two sets of experimental trees, polyethylene sheeting covers the area occupied by the "dry" trees, while canvas irrigation hoses supply the "wet" trees' area. Installations for measurements include neutron probe tubes, tree access scaffolding, and dendrometer bases.

261. The University of Washington study of the influence of environment upon the quality of wood of Douglas-fir concentrated on techniques for quantification of the development of xylem, as follows: (a) optical evaluation of structure, (b) mathematical description of formation, (b) biochemical processes of production, and (d) minimal media for culture of excised cambial tissue of Douglas-fir.

262. An Alabama study developed recommended microtechniques for preparing wood specimens for cytological examination.

263. The first of four projects dealing with wood moisture at the University of New Hampshire, aiming to improve dry kiln practice for hardwood lumber has progressed toward a method of continuous and rapid evaluation of shrinkage strain during kiln drying of wood without alteration of the piece. In a full scale charge of red oak dried on Forest Products Laboratory schedule, the photoelastic coating on selected planks permitted comprehensive photographic record of the sequence of strain development while the lumber was drying from initial moisture content of 40-80 percent to a final moisture content of 10 %.

264. The project at the University of Massachusetts has an improved specimen design to study set development in wood under compression perpendicular to the grain. So far, of 12 hardwoods, American elm has shown the greatest set development.

265. The third wood moisture study is at Washington State University on relationships of wood at high temperatures. Both grand fir and western redcedar evidenced thermal softening of wood at temperatures below 100°C. Grand fir wood extracted with a series of conventional solvents (water, alcohol-benzene) proved more hygroscopic than whole, unextracted wood. Additional extraction with DMSO rendered wood even more hygroscopic. Thus, extractive components of wood significantly decreased its equilibrium moisture content.

266. The last of four studies on wood moisture is at Oregon State University on permeable and refractory western hemlock. Seasoning is difficult in hemlock with zones that don't dry at a rate proper for other portions of the piece. Information on permeability to moisture between wet zones and normal wood will assist in developing schedules to prevent wet pockets in seasoned lumber. Rate of flow of nitrogen gas and air was used to measure permeability of heartwood samples from fresh-sawn boards with visible zones of either high or low moisture contents. The rate of flow of high-moisture zone samples was decreased up to 20-percent, compared to samples from adjacent zones of lower moisture content.

267. Of seven projects on mechanical properties of wood, one at Washington State University deals with dynamic strain and piezoelectric effect in wood. The E, or modulus of elasticity values, were predicted with use of a nondestructive strain wave propagation method in a feasibility test on 6 Douglas-fir logs. The top-grade achieved an E value 1.4 times that of the lowest grade log, with the other four logs at intermediate ratios of 1.3 to 1.1. Then logs were cut into 2 x 4's



Fig. 25- Hand-held probe used to measure strain wave propagation, for log-grading. (Washington State University. Statement 267.)

of 16-foot length. The E values measured on lumber by log origin showed that of the top log 1.5 times that of lumber from the poorest grade log. Lumber from other four logs had intermediate E's, though with some shift in rank predicted from the log cuts. Probes sensitive to piezoelectric effect of wood give good correlation with conventional strain-sensitive transducers. (See Fig. 25.)

268. In the project at the University of Maine on adapting native woods to improved products, the correlations established between fracture and elastic strength in eastern spruce permit commercial electro-mechanical stress rating of the material. Also, the relating of production rates of harvesting equipment to stumpage measures and land

characteristics has established prediction equations to develop input-output criteria for tree-length harvesting operations that should facilitate improved operational planning and management techniques. An improved system for cost control and financial reporting readily adapted to electronic data processing was developed for sawmills of low to moderate production output.

269. The study initiated at the University of Idaho on white fir aims to relate wood-grain angle, modulus of elasticity, and modulus of rupture to each other, to contribute to improving lumber grading and to eliminating excessive safety margins.

270. At North Carolina the project to characterize mechanical properties of wood in terms of mathematical models focused on stress distributions in an orthotropic beam, calculated from high-order equations differed from predictions by elementary bending theory.

271. In the Idaho study on Inland Douglas-fir, specimens from one dominant tree provided data on specific gravity, percent summerwood, and ring width that relate to stress perpendicular to the grain.

272. In a Pennsylvania study of individual wood fibers and their strength, techniques were established to test single fibers in tension parallel to the thin axis. Douglas-fir bark fibers were glued together at the ends by an epoxy adhesive, and successfully carried through a testing jig that provided test results as follows: Ultimate loads ranging from 17,000 to 61,000 psi; Modulus of Elasticity, 0.3 to 1×10^6 . These data on strength of Douglas-fir bark fibers are believed to be the first of the kind.

273. The last project on mechanical properties of wood at the Agricultural Experiment Station of University of Kentucky, focuses on stress at the level of the cellulose molecule of wood fibers. This study has yielded a remarkable finding that the intrachain hydrogen bond in cellulose contributes much more to the stiffness of the cellulose chain than generally anticipated. A computer program that can accommodate a large number of variables has been written to solve for stresses in the larger-than-molecule components of the fiber wall.

274. A study at the University of Washington is one of three on how wood properties can influence the efficiency of industrial processing. Here the question is how does the veneer cutting process change the anatomy of wood and affect the performance of veneer in plywood? On some of the types of cell failure which occur in commercial veneer of Douglas-fir and western hemlock, examination indicated a pattern related to the place where rupture occurs in plywood adhesive test specimens. Failures in the veneer due to the cutting action may be a limiting factor in the performance of plywood.

275. Whether wood fats in yellow birch interfere with wood adhesion at the temperatures required to dry veneer is a question investigated at the University of Michigan. Heating wood in a water saturated condition at 100°C for 21 hours increased free fatty acid concentration in ether-soluble extractives. However, the total ether soluble fraction did not change to permit any soluble products formed to migrate out of the wood. Of a total extractive, a 60-percent saponifiable portion showed no change with heating. Fats included 18-carbon unsaturated acids, at 20 times the level of stearic acid, and palmitic at twice this level; the 20- and 22-carbon acids appeared next in concentration.

276. A University of Washington study on surface properties of wood and character of resin as related to wood adhesion started on Douglas-fir. The two testing methods developed, the cross-lap, and internal bond test of the tension-perpendicular-to-the-glue-line type, were evaluated on a small-scale adhesive joint and an Instron testing machine. Preliminary tests were: summerwood vs. springwood, sanded vs. unsanded veneer surface, and, without and with solvent-extracted veneer. The internal bond type had good reproducibility adapting it as a testing method.



Fig. 26- Bark fragment from mature Douglas-fir with light-colored cork layers that yield wax and fine chemicals. (Oregon State University. Statement 280.)

277. One of four projects on wood utilization potentials is at Auburn University on degraded hardwoods as a source of "partridge wood," or "pheasant wood" products of high aesthetic value. Only small dimensions of degraded materials can be cut from most decayed logs, standing trees, or wood debris, due to uneven degradation and unusable portions. Harvesting of degraded hardwoods might accompany usual logging.

278. A project on growth-quality evaluation of the wood of Missouri's commercial tree species has surveyed pulping potentials of several hardwoods. Sycamore, silver maple, black gum, sweetgum, American and slippery elms were sampled at breast height by increment cores. These were sectioned to provide pith-to-bark data on original moisture content,

percent extraneous substances, specific gravity, fibre length, and cellulose content. Also, thin sections of "shake" defect in oak and walnut evidenced, microscopically, that "ring shake" occurs between fibres as opposed to rupture of fibre cell walls

279. The Auburn University study on anatomy of figured wood located southern pine with curly figure in southern Alabama.

280. Of four studies concerned with bark, the project at Oregon State University deals with structural variations of Douglas-fir bark. Photographs and samples of bark have been taken from 227 trees representing a wide range of sizes, ages, and growing sites at three major localities in northern California and Oregon. (See Figure 26.) The most obvious structural variations of bark between trees of the same age are the thickness and orientation of the cork layers in the outer bark. External configuration of bark results from numerous plate-like, radially-oriented breaks extending from the bark surface to the innermost cork layer and apparently associated with fungal activity. The percentages of fibers (sclereids), fines and cork resulting from grinding whole bark vary little between trees in a single plot, except at breast height. Lengths of sclereids and sieve

elements do not vary much between sites. The average calorimeter tests on samples from several trees indicated heat values in BTU's per pound of material were: fibre 8,970, fines 9,650, and cork 11,250. Milled samples of whole bark had heat values proportional to content of fiber, fines, and cork; high BTU is associated with high cork level.

281. This project at Oregon State University deals with the reaction of the flavonoid compounds obtained from bark on exposure to gamma radiation. Gamma radiolysis of the bark flavonoid, quercetin, in ethanol gave numerous degradation products under aerobic conditions, whereas under an atmosphere of nitrogen it resulted in molecular rearrangements but with retention of the flavonoid structure. This suggests retention of the antioxidant capacity important in developing flavonoids suitable for preserving foods.

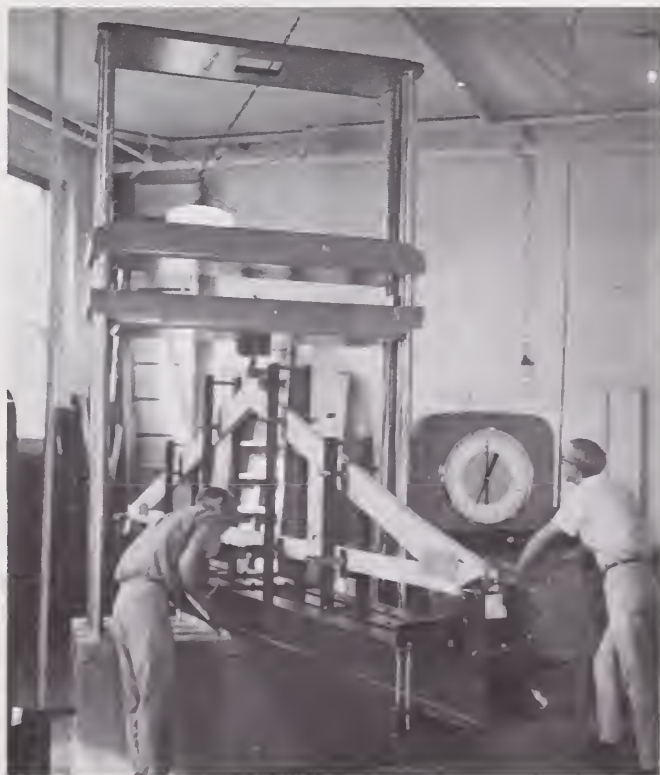
282. This project at Georgia involves physiology research on some of the factors that influence storage of carbohydrates in root bark of loblolly and slash pine. Available data indicate that storage of reserve food in root bark is closely related to the total growth of the pines. This study examined the influence of DBH, total height, length of live crown, crown width and crown density on storage of reserve food in roots of 5 ramets in each of fifteen 12-year-old clones of shortleaf pine. The carbohydrate analyses made according to Shaffer-Somogyi method (Heinze and Murneek) revealed no significant difference in food content among the clones tested. Of correlations tested between food content and tree characteristics, crown density proved the only significant factor.

283. In the final study of bark properties at Louisiana Polytechnic Institute, two-year tests of southern pine bark as a mulch for hybrid roses resulted in a higher flower count than on plots with conventional mulches.

284. This is one of two McIntire-Stennis projects on wood machining now active at the University of California. A phase on the mechanics of cutting deals with cutting forces for various conditions of cutter rake angle, grain angle, cutting speed, chip thickness, and moisture content of Douglas-fir and maple. Here, the elastic foundation of workpiece, holder, machine, and machine tool contributed significantly to the type of chip formed as well as surface finish characteristics. This foundation was made as stiff as possible to reduce this effect to a minimum in the studies. Here friction plays an important role in the cutting process that demands further study. The surface finish produced was related to only a few of the tested parameters contributing to variation in cutting force. Major contributors were chip thickness and workpiece grain angle. A miniature veneer cutting lathe has been designed to cut short bolts, with provision for adjusting the knife rake angle, and oscillating the knife. Another phase of the project deals with the effect of machining and surface preparation on glued joints, and on laminated and box beams. One-sixth scale models of laminated and box type beams indicated that machining flaws and dimensional inaccuracy were major causes of glue failure, and that beam geometry determined load carrying capacity.

285. Veneer from young-growth redwood represents the subject of a newly initiated McIntire-Stennis project at the University of California. Its activation included recruitment of a wood scientist; a survey of literature on aspects of young-growth redwood which might relate to use for veneer; and, contacts with the redwood industry that enlisted their support for the project, particularly to supply study logs. The provision of equipment and the initial cutting experiments are scheduled to start by the close of the year. The equipment includes modification of a heavy duty milling machine to serve as an experimental lathe, necessary instrumentation, and a temperature controlled soaking tank for pre-treatment of log sections prior to cutting. In addition, an existing steam chamber will be used in the evaluation of steaming as a pre-treatment.

Fig. 27- This prototype structure for load tests facilitates prediction of internal forces and deformations of wood. (Purdue University. Statement 286)



286. The Purdue project on analytical design of wood trussed rafters deals with principles applicable to wood frames in prefabricated building. Analytic data from experimental analyses of 14 full-scale trusses, tested last year, were compared by computer analyses devised for the purpose of predicting internal actions (stress and moment) and deformations of the building components. (See Figure 27.) Prediction of the actions was found to be adequate for engineering purposes; however, prediction of deformation was unsatisfactory for truss types. Improvements were made in the analytic system. The improved system achieved success against the elusive problem of predicting the deformation of a complex wood structure under load. The analytic form and success with the system opened the way for predicting deformation increases in structures loaded for an extended time. This poorly understood phenomenon, called creep, is associated with viscoelastic materials including wood and has received only brief and sketchy engineering treatment.

287. The North Carolina project deals with systems analysis in the wood processing industries. This focuses on collection and analysis of economic data for managers to predict headsaw production as a function of input variables. Field development of an electronic recorder

Recording sensor of carriage position to predict headsaw production
(North Carolina State University at Raleigh. Statement 287.)

Fig. 28- Positioning transducer attached to sense sawmill carriage position.

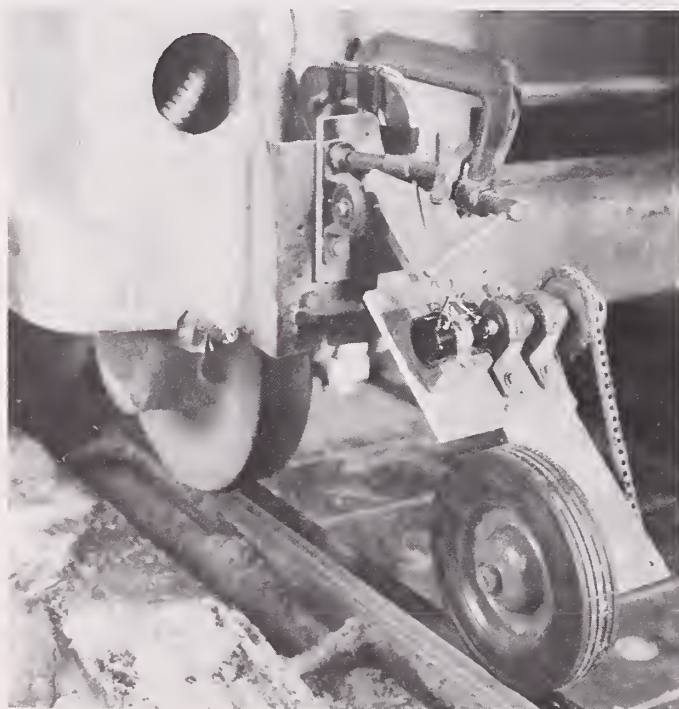


Fig. 29- Scientist checks installation of instruments on headrig of commercial mill.



installation on an operating sawmill headrig followed laboratory trials on the School sawmill. (See Figures 28 and 29.) Field tests indicated that circuitry and recording systems required modification to increase durability under operating conditions. Besides recording the sawmill carriage position, with respect to time, design, and testing was undertaken of event markers to record time that saw was in contact with log, and time of operation of log turner. An automatic photography system was also installed to record log turning. This apparatus should allow accurate measurement of the parameters concerned in headsaw production. This is the first step towards quantitative analyses of alternate systems.

288. Of two Kentucky projects dealing with design using Appalachian woods, one analyzes stress distributions in composite pole structures to develop better designs, suitable fabrication, and experimental techniques for test specimens. A computer program was written for the completed analysis of the behavior of wood poles wrapped with a structural jacket of reinforced plastics. The program considers a number of variables, such as, species of pole timber, diameter, length, butt embedment length, thickness of laminated jacket, type of reinforced plastics and applied forces. Fabrication of test specimens has used a cloth-reinforced liquid resin system that cures at room temperature and a pre-impregnated material with unidirectional reinforcement that requires radiant energy to cure. Design already completed is the fabrication of a steel testing apparatus designed for full-size laminated poles.

289. The second project deals with fastening and joining techniques for fabrication of built-up beams and structural frames, and under varied duration of load, and initial wood moisture content. Replicated glued specimens of three sizes of rough-sawn or planed red oak lumber having high initial moisture content were fabricated with resorcinol and casein adhesive and then subjected to two different drying rates. Within two days of fabrication and after drying to 10 percent, specimens are tested in compression. Triangular wood frames with glued finger joints at the corners were analyzed. They proved very strong, their joints could be assumed completely rigid for purposes of analysis. Large corner joints are being tested with SR-4 strain gauges oriented to map the stress pattern in the joint region.

290. In the Mississippi project on production efficiency in the wood products field, data were collected during 1966, and, currently are being programmed for computer analysis.

291. One of two West Virginia projects on the manufacture of hardwood lumber deals with the utilization of black cherry. The yield in furniture flat stock from 80 low-quality black cherry trees sawed with

a bolter saw was 20 percent greater than the estimated yield on a long-log basis. Overrun from sawing large, straight bolts was small, thus indicating that the effectiveness of a bolter mill is evident when low-quality logs or bolts are converted, chiefly due to reduction in loss from sweep and taper and fuller utilization of large branches and tops. Concerning sawing procedure, cross cutting followed by ripping increased yield; however, upgraded cuttings were obtained from ripping first. The quality of the dimension stock produced by the bolter mill was comparable to that produced by conventional sawmills.

292. This project on problems of wood construction in residences reports returns from a preliminary mail survey of residential builders and contractors in Iowa. Conventional wood-frame construction is more common than pre-fabricated components. Over 70 percent of the builders purchase three-fourths or more of their wood construction materials from local retail lumber dealers; however, builders who purchased from retail sources were typically low-volume builders. Two-thirds of the builders considered that shrinkage and warping were major problems associated with the use of wood; twenty percent indicated that high prices and poor quality were problems.

293. The Pennsylvania project on kerfless cutting with a knife succeeded in slicing yellow-poplar flitches to thickness of 1/4 inch with installation of air clamps to reduce flitch movement during the slicing. Laminated beams consisting of four sliced laminae contained with sawn lamina showed substantial reduction in all strength values except the modulus of elasticity. This reduction is attributed to the discontinuities present in the lamina caused by slicing.

294. In the project on efficiency of methods of handling lumber in West Virginia, field studies were completed at 40 hardwood mills.

Seasoning, Preservation

295. The Southern Illinois University project on vibrational measures of moisture in wood has not reached the stage where findings can be reported. Special conditioning chambers to generate moisture gradient in wood have been set up. Electronic equipment required for the project has been developed and is in the process of final refinement. Since preliminary testing revealed that cottonwood has excessive tension wood, yellow-poplar has been substituted. Some 800 test specimens have been prepared, and characteristics such as density, growth ring angle, percentage of summerwood determined. These specimens currently are being conditioned in a saturated environment.

296. This University of Illinois project examines effects of high treating temperatures and pressures on the preservative absorption into Douglas-fir, and on its strength in bending and stiffness. Analysis of variance indicates significant interactions of pressure, temperature of preservative, and moisture content of wood in each of three sets of data. The collapse of wood cells in some specimens treated to high temperatures and pressures is influenced by time. Some specimens show more collapse after brief treatment under pressure and temperature than when the time period is greater. Possibly some stress equalization occurs in the wood after longer periods of treatment.

297. The Minnesota project on prefreezing to speed drying of important lumber species has commercial-scale tests on redwood under way to compare results under normal operating conditions with preliminary laboratory results.

298. To develop chemical modification of wood, fundamental research at Iowa deals with the effect of processing on the solution and diffusion of vapors in wood. Specifically, the effects of drying temperature and rate, solvent exchange drying and the resulting internal stresses are under study.

299. In the currently active phase of the Mississippi project, results of exploratory tests conducted on Class 6 poles and on piling sections of southern pine indicate that method of drying has a significant effect on static bending and compressive strength of round timbers.

300. A North Carolina project deals with the development of gas phase treatments for wood to attain modification of the properties in sizes difficult or impossible to treat by liquid phase methods. Earlier modification of the equipment and techniques has shown that helium gas will completely permeate the void structure of highly evacuated 4-inch diameter by 18-inches-long specimens of four different species of wood in 20 seconds to 20 minutes. Specific gravities of the wood substance calculated from these data are in good agreement with values determined with sawdust. Preliminary measurements using pentane just above the boiling point give similar penetration indicating that little condensation of pentane occurred in the fine capillary structure. The past year's work concentrated upon penetration and reactivity of vapors to impart dimensional stability. These smaller scale measurements with formic acid, acetic anhydride, and ethyl isocyanate, (the latter together with dimethyl formamide vapors) have shown that the reactant vapors penetrate the void and diffuse into the cell walls to impart dimensional stability to the wood. Thus, technically, the progress appears promising.

301. This Virginia project aims to evaluate analytically the factors involved in seasoning wood, solve the equations governing the seasoning, and modify factors affecting the rate of seasoning. Equations for drying of larger dimension (8/4) yellow-poplar lumber in the range below the fiber saturation point were solved on the computer, using a wide range of values for the diffusion coefficient. Drying rates of lumber, however, did not agree with solutions based on diffusion coefficients from the literature. A computer program is being developed to estimate diffusion coefficients based on the early stages of drying before the midplane of the wood has begun to dry.

Pulp, Composite Products

302. A Purdue project on the relationship of macrostructure to strength of wood particleboard aims to develop an analytical design for particleboard. The review of the materials science literature continued with emphasis on papers pertaining to non-wood composites, such as re-inforced plastics and metal alloys. A method for predicting the elastic properties of particleboard based on the concept of strain energy shows promise as a first approximation. Actually this method predicts an upper and lower limit for the particular property of the material being investigated. The possible adaptation of existing structural analysis theory for frames to determine internal forces and displacements in externally loaded particleboards was investigated. Although not initially successful, this exercise did indicate the possibility of success, if necessary modifications to structural theory can be devised.

303. The Alabama project on wood as light aggregate in concrete deals with the effect of wood-particle geometry on the strength, workability, appearance, and general utility of wood-concrete products. Following the completed summary report, further data are being analyzed.

304. This Georgia project on exterior wood-glue composites deals with such process variables as particle geometry, wood density and resin distribution on board performance in exterior use. Needed processing equipment which have been built are a spray chamber, a mat former, and several pressing frames. Following tests on the completed equipment, certain operational refinements are being made.

305. The development of various types of particleboard made from Engelmann spruce and lodgepole pine is the subject of this Colorado project. Since starting last March, the major activity was the design of equipment to produce and evaluate particleboard panels. Each individual step in the production process is mechanized in order to minimize experimental variation. A chipper, conditioning drum,

particle sizer or separator, blender, mat former and hydraulic hot press constitute the laboratory-scale working unit. The chipper is a modified metal shaper capable of producing wood particles of controlled geometry with any desired grain orientation. From the chipper the particles are placed in a 4-foot diameter conditioning drum. In this tumbling drum the wood material can be conditioned to a desired moisture content. The particle-sizer or separator utilizes a series of screens of decreasing mesh sizes which vibrate to divide the wood particles of specified thickness and widths into groups of uniform length. Material leaving the separator is ready for storage in sealed containers and is sized according to particle geometry, moisture content and species. Synthetic resin is applied to the wood particles in a large "tumbler" blender equipped with an internally mounted spray gun that is fed by either an air or airless system. This step in the process appears to be the most critical. The sprayed particles then proceed to the mat-former. This device receives the resin coated particles on an endless conveyor belt that drops the material through a separating well onto an oscillating caul to produce a uniform mat. The final step in the process is the hot pressing cycle. A single-opening hot press, capable of providing a 1500 psi pressure over its 24 x 24-inch oil-heated platens has been ordered and preparation made for installation when the hot press arrives.

306. Of two North Carolina projects on pulp and paper, one deals with relationships between wood fibre properties and paper quality. The aim is to predict the performance and quality of pulps and paper manufactured from fibers having widely varying morphological, chemical and mechanically developed properties. A study undertaken within this subject heading has spurred renewed research interest on the relationship of fiber morphology to paper quality. Initial results indicate that cell wall thickness, contrary to earlier thinking on importance of tracheid length, of a coniferous wood fiber is likely the most important single morphological predictor of kraft pulp and handsheet paper qualities. Other wood characteristics, such as specific gravity, fiber length, and various property ratios can be used in the prediction of paper performance; however, the cell wall appears to dominate the response patterns. The research is advancing as follows: Collection of fiber morphological data on 24 selected loblolly pines is 75 percent complete, and pulping data on test trees has been largely acquired. The influence of beating upon fiber morphology, the relationship between zero span results and fiber morphology, and pathways of liquor penetration are under examination.

307. This project in North Carolina aims to investigate some of the factors affecting the penetration of aqueous writing inks into paper. Knowledge of these factors will assist in developing better testing procedures for control of manufacturing processes in the paper industry. The most important variables affecting the time of penetration of writing inks through paper were found to be temperature, pH, and type

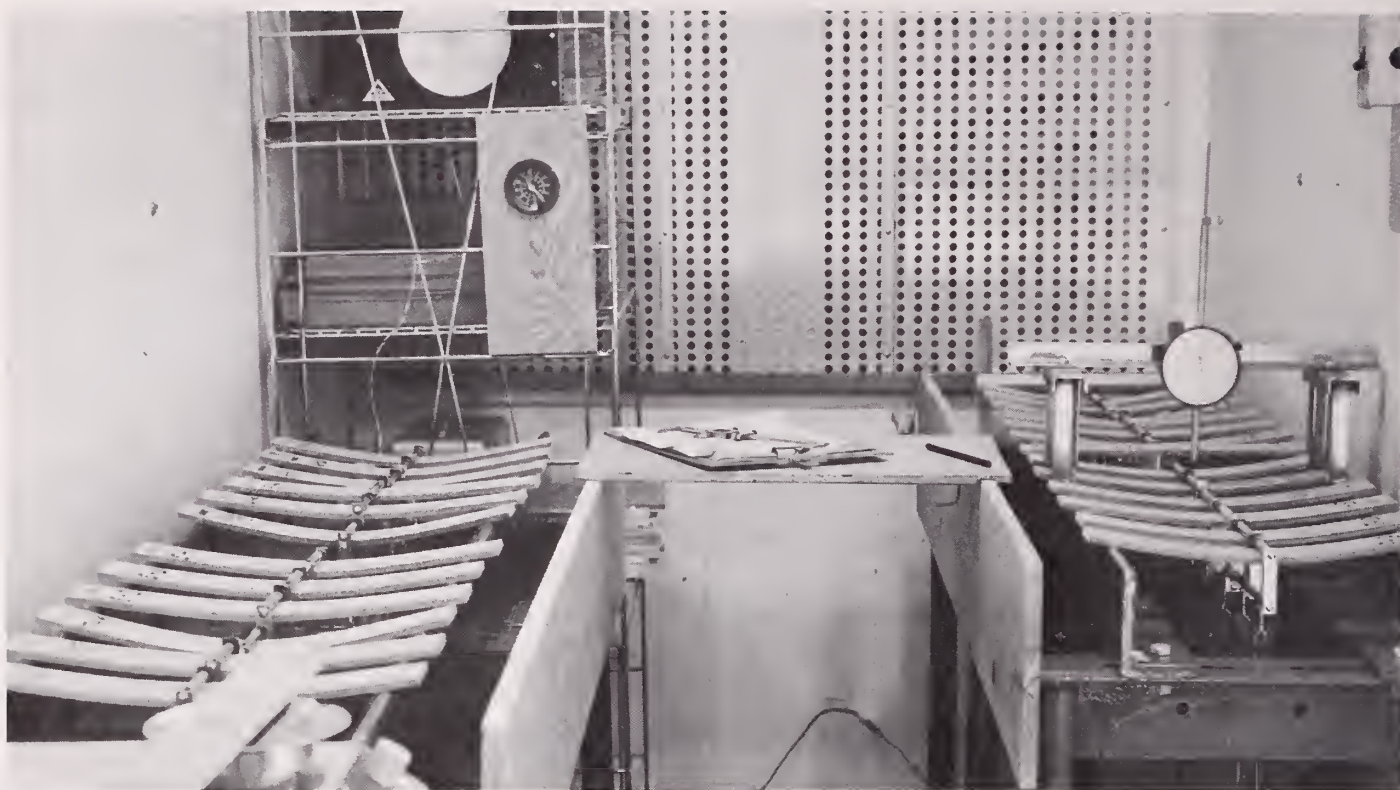


Fig. 30- Aspen hardboard bending specimens tests under constant loads in controlled environment, in study of flexural creep and stress-rupture. (University of Minnesota. Statement 308)

of dye used in the ink. The commercial testing instrument used for optically determining the endpoint was found to work well except for lack of temperature control. Recommendations were made for improving temperature control, and possible standardization of testing inks. With the optical endpoint used, a large difference was obtained in penetration time for test inks depending upon which side of the sheet was used. Structural differences may account in part for this phenomenon, and further study of the mechanism of ink penetration through the sheet appears warranted.

308. A McIntire-Stennis project on creep and stress rupture in aspen hardboard got under way in Minnesota. Short-time (48 hours) flexural creep tests at two moisture content levels were completed on both dry-process and wet-process hardboards. (See Figure 30.) These should determine the effect of load level, type of board, and moisture condition or change on the deflection which gradually occurs under load. A series of static bending tests at the same moisture condition and at temperatures from 0°F. to 190°F. was completed. Such rate equations tested on creep in plastics, show promise for hardboard once activation energy values are determined. This could mean that accurate prediction of deflection of hardboard, loaded up to six months, can be made from static bending tests of only two minutes' duration. A portion of our long-term (4000 hour) bending tests that have been completed will be used to check predictions made from our static test data.

Forest Economics

Research in forest economics assumes increasing importance with the intensification of competition both for utilization of forest lands and in the market place. The McIntire-Stennis program has strong representation in forest economics research as evidenced by the following progress statements on Policy and Forest Products Marketing.

Policy

309. Inventory control in lumber manufacture is the object of a University of California project. A preliminary survey carried out on a wide range of lumber companies indicated desirability of concentration on a simpler type of lumber operation--namely, stud production. Contacts with 20 lumber companies producing studs yielded detailed information from twelve. Information included data on costs, labor inputs, storage facilities and typical production and inventory levels. To portray a representative stud mill, linear programming was used to specify optimum inventory and production levels over a 12-week period.

310. To appraise the forest land taxation situation in Illinois and to consider alternative methods, in view of possible land consolidation, is the objective of a Southern Illinois University project. Analysis of property tax responsibilities, assessments, and sales values on a per-acre basis for sample properties in the 17-county area confirmed disparities between assessment levels and market value of forest and associated lands. Individual assessment ratios and tax burden ratios within 12 property-holding stratifications indicated discrepancies. However, the infrequency of property sales has given rise to the need for value predictors. To handle this situation an IBM computer analysis is being designed to consider rural land within a framework of all possible productive-consumptive uses. It will provide value indicators for variables which consider both internal and external influences of the property value. Planimetric mapping for the sample areas is being consolidated to uniform scale to show spatial association of the variable (See Figure 31).

311. Financial aspects of silviculture in young mixed oak stands are the subject of a project in Missouri. Oak sawtimber increased in stumpage value from \$0.31 per tree of 11 inches DBH to \$1.75 at 20 inches. Although 11-inch trees on all sites had about the same value, 20-inch trees growing on good sites had a mean stumpage value of \$2.11, medium-site trees \$1.75, and poor-site trees \$1.35. Slow-growing post oak required 90 years to attain 11 inch DBH; black and scarlet oaks only 60 years.

312. This Wisconsin project seeks to identify opportunities or barriers to promising forestry related income and employment, and estimate their potential effects on the poverty problem in Menominee County. This is an area of low income and unemployment, although total wealth measured is adequate to provide a level of living equal to that in prosperous neighboring counties. A considerable portion of much of the county wealth is in the form of standing timber. However, much of this timber produces a low rate of return in comparison to available alternatives in hardwood veneer manufacturing and processing of hardwood lumber. Beyond several institutional barriers preventing conversion of part of the timber, there is sufficient latitude in Wisconsin's law, which requires sustained-yield management of the Menominee forest, to permit an increase in timber cut and thereby make capital available. Another potential source of capital for manufacturing is in making a small part of the forest available for a state park. Suggested modification of present forest management would treat aesthetic values as dominant on portions of the forest suited for major recreational use, but would treat timber values as dominant on areas not included in the recreational zones. Where aesthetic and recreational values are dominant heavy stands of timber would be maintained, but where timber values are dominant, stands would be reduced to the economic optimum stocking.

Fig. 31- Photogrammetric, planimetric and tabulative aids used in quantifying the variables under study in a forest property taxation project (Southern Illinois University, Statement 310.)



313. A few months' operation of this new Wisconsin project has refined the objective to the measurement and prediction of changes in technical coefficients relating inputs and outputs in the forest industries. Preliminary investigation suggests input-output analysis as the most useful format. The paper "The Political Economy of Allowable Cut" developed this approach and suggested the potential usefulness in a current forest policy problem area. With this analytical framework, information on technological change is an important component in prediction of (a) future demand for timber-based products and timber resources; (b) economic returns from investments in timber management, production facilities and marketing efforts; and (c) costs and benefits of major changes in institutions, markets, and technology.

314. This project aims to determine the applicability of linear programming to receptive forestry firms in New Hampshire. A new technique developed for solving linear programming problems appears simple for the layman to understand and use. Application of this technique is under test in a large forestry firm. As results become available they should be enlightening on attitudes of forest industry toward linear programming.

315. This Virginia project seeks to increase the efficiency of forest management decision-making. A primary objective of integrated forest products firms is to minimize the cost of supplying the mill with raw material. During the year, the wood procurement operations of an integrated forest products firm were described by a system of linear equations. These were solved as a linear programming problem for wood procurement from both company-controlled and outside wood-supply sources. The optimum wood procurement policy covered a period of 20 years with provision for controlling enough raw material to supply half the mill's wood requirement during a second 20-year period.

316. A North Carolina project on analysis of the foundations of American forest policy includes a short history of the Federal-State-Industry Cooperative Tree Improvement Program. This covers development of cooperative policy in this new and important area of forest management research and operation. Data were based mostly on personal interviews, and on the criteria used in planning and measuring the results of forestry development programs, especially for so-called "depressed areas". The results of this investigation should be helpful in focusing attention on the factors which will help improve procedures for selecting forestry development project priorities, for allocating development funds, and for securing better Federal-State-Industry cooperation for such projects.

Marketing Forest Products

McIntire-Stennis funds are supporting much needed research addressed to clearer understanding of the market mechanism and factors that operate against efficiency in marketing and pricing. Studies initiated deal with market channels and structure, market forces and performance, prices, and use prerequisites. The great diversity of forest products and their many unique uses necessitate widely different types of buyers. The market for forest products, unfortunately, has not developed desirable degrees of efficiency and stability. This is especially true for the farm woodlot and other small ownerships. The identified problems are susceptible to research attack to learn how greater efficiencies can be realized. Marketing problem solving will continue to warrant study so long as we have a free, dynamic society. Descriptive studies should lead to comprehensive analyses directed specifically toward developing more effective marketing of forest products. Altogether, 14 McIntire-Stennis projects, some of them just getting under way, have reported progress on forest product marketing research. The University of California has 2 comprehensive studies underway attempting to develop dependable bases for forecasting. Both investigations require development of appropriate methodology and the verification of conceptual models.

317. Methods of estimating long-range timber supply is the subject of one California project. At the present stage, results are entirely technical. A model developed analyses marketing surplus growing stock over a number of successive time intervals, with different timber demands in each period. Within the tight constraints inherent in models, conclusions are tentatively as follows: in the case of a market with a single seller, an even-flow policy of surplus disposal will only maximize social returns in the special case where demand is constant over time. Where surplus stocks are held in part by one large seller and in part by numerous small sellers, the large seller can achieve neither an even-flow nor a maximum social returns policy. Such a seller could approach either goal by adopting a compensatory supply policy; however, this would force him to market his supply in the periods of weakest demand with an unfavorable effect on his returns. The significance of these conclusions for timber supply policy must await progress on analysis of timber supplies other than surplus growing stock.

318. The second California project deals with short range forecast of market characteristics in the redwood lumber industry. Numerous econometric models have been used to forecast characteristics such as new orders, shipments, and prices. Forecasts were compared with actual

data for a test period with good results. Of several techniques tested the promising were selected for further study. Interviews have been conducted with companies producing redwood lumber to verify the realism of the models employed.

319. An economic analysis of the forest marketing structure in Maryland is in progress. Data were collected by personal interview of 114 sawmill operators, 67 producers who cut, skid, or truck timber, and 97 landowners who sold timber in the past year. Preliminary analyses indicate that owners have little knowledge of the value of timber sold, and sale contracts are loosely worded. More than one-half of the farmers contacted reported oral agreements. Sales of timber were often related to crop failures or other reasons for needing extra cash. Both the producer and sawmill operator have been characterized by frequent entry and exit. In an attempt to realize better utilization of labor and equipment some producers are thinking in terms of vertical integration. Producers generally have a good credit rating in order to buy and pay farmers in advance of receipts.

320. A study of the restraints to aspen lumber suppliers for Minnesota sawmills aims to identify factors causing lack of supply response, also, problems of input, production organization, and distribution. The tracking down of owners of sawmills in the 12-Minnesota-county study area discovered the situation in 1966 compared with 1955 records. Of a total of 631 sawmills that had been active in 1955, only 35% were operating in 1966--65% were not active. Moreover, of the 455 sawmills active in 1966 only 48.5% of the owners were the same as in 1955--51.5% are new. This revealed that it isn't always the same owner who comes back into business after a shutdown, and, the resulting turnover of owners was larger than expected. To deal with so many new owners has implications important to the conduct and results of this project on marketing and production problems.

321. This Idaho study deals with the potential markets for cut-up lumber stock. The aim is to determine the potential demand, the product specification of potential consumers, and the feasibility of northern Rocky Mountain producers providing the desired cut-up stock products. Data obtained from first stage questionnaires to larger wood-using firms indicated that 40% of those contacted intend to increase or start the use of cut-up lumber. The major interest in increased procurement came from consumers in the Midwest and East. The qualities most desired were machineability, dimensional stability, and resistance to splitting--with little variation by size of customer.

322. The project on hardwood utilization and marketing at Michigan State University seeks improvement of methods of procurement, production, and marketing hardwoods. Following the completed phase on residue utilization the information obtained on production methods and costs,

operator and machine capabilities and material handling has been analyzed and results are under test by a cooperating firm. A cost accounting system developed provides information for management decision-making.

323. The study on roundwood use and requirements on rural ownerships in Vermont found under-utilized tree species a logical source of treated posts and poles. To replace diminishing northern white-cedar, buyers must be convinced of qualities of the treated products.

324. The study on industrial markets for shipping-lumber in Vermont found the largest users were manufacturers of stone and cement products, with manufacturers of machinery and tools second. Users of shipping lumber purchased direct from the sawmills. Some 85 percent of the volume used was softwood, and half of this was native spruce.

325. A Kansas study found the wood-using industry reluctant to expand due to concern over dwindling raw material.

326. The availability, consumption, and species preference for lumber and dimension products as influenced by marketing procedures of lumber dealers and building contractors is being investigated in Mississippi. Homeowners account for 51 percent and building contractors 42 percent of total sales by retail dealers. Builders, the most influential group in determining the amount and species of wood used in construction, purchased largely from wholesalers and producers. Wood still is the primary material in house construction, in the State; however, of the houses constructed during the past 5 years only 7 percent contain wood as the primary siding material, 80 percent have concrete slab foundations, and 70 percent have metal window units.

327. A Texas study on marketing of wood from producer to mill to industrial user summarized data on sawmills, and pulpwood industry, and is surveying lumber wholesalers, commission men, and brokers.

328. The Louisiana State University School of Forestry and Wildlife Management study on market distribution patterns and the major sources of lumber are being analyzed.

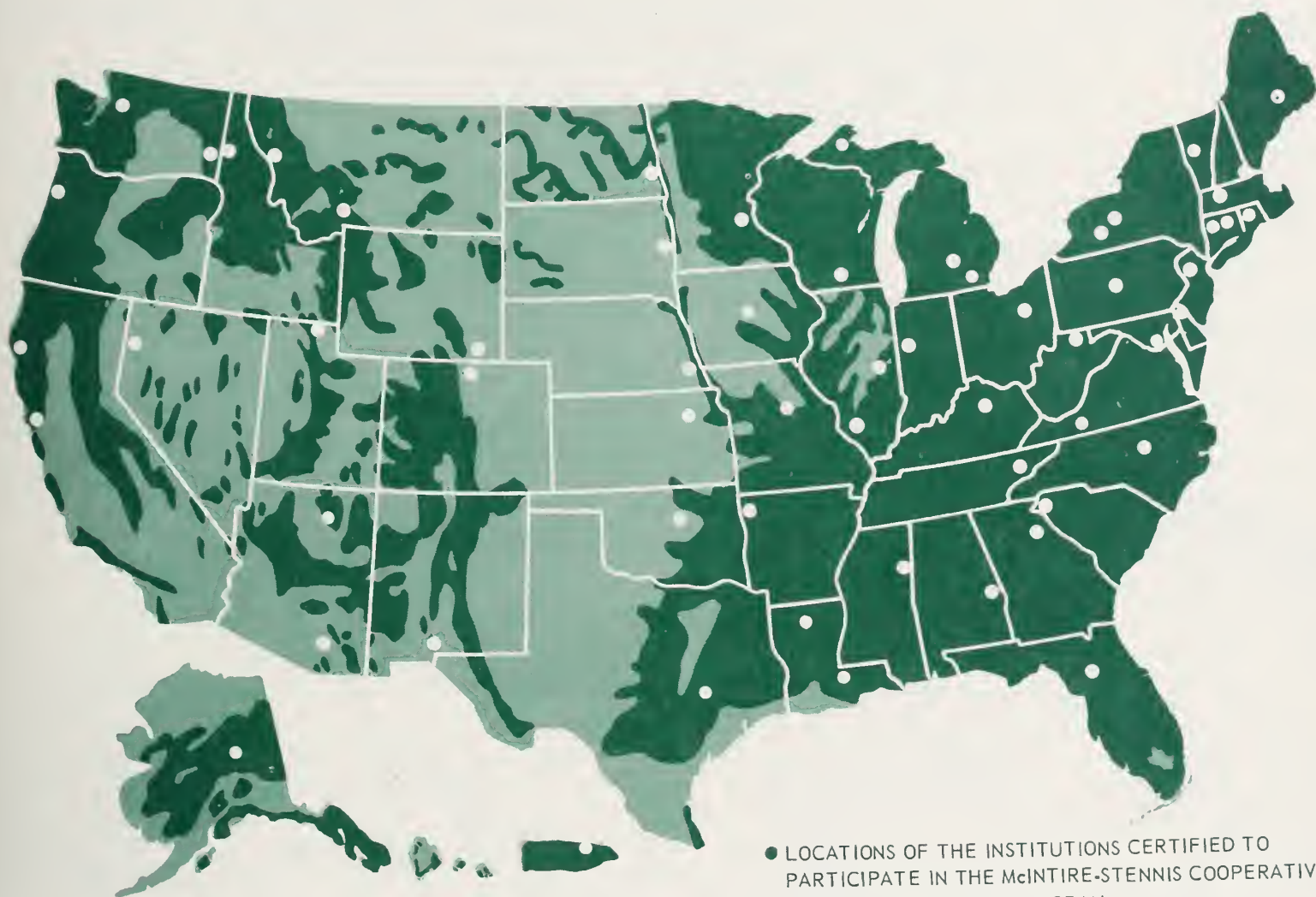
329. In the University of Alaska study of marketing chips for pulpwood from the Haines area, data collection is under way.

330. The Montana study of marketing lumber has questionnaires for wholesalers and retailers.

Projects, Progress and Participating Scientists
McIntire-Stennis Program - 1966

| University or
Experiment Station | Progress Statement
numbers | Proj. Grad. Publ.
Sci. Stud. | | |
|-------------------------------------|---|---------------------------------|------------|------------|
| | | <u>no.</u> | <u>no.</u> | <u>no.</u> |
| Alabama-Auburn U. | 24. 58. 92. 131. 262. 277. 279.
303. | 9 | 2 | 6 |
| Alaska, U. of | 10. 11. 31. 48. 329. | 4 | 1 | 2 |
| Arizona, U. of | 132. 194. | 3 | 2 | 0 |
| Arizona, Northern, U. | 51. 173. 227. 249. | 4 | 1 | 1 |
| Arkansas, U. of | 116. 133. 134. 135. 239. | 6 | 8 | 7 |
| California, U. of | 53. 107. 119. 120. 161. 181.
284. 285. 309. 317. 318. | 10 | 17 | 6 |
| California- Humboldt | 9. 174. 186. 187. 205. 233. | 6 | 5 | 1 |
| Colorado State U. | 75. 185. 230. 305. | 5 | 7 | 2 |
| Connecticut, U. of | 208. 212. 219. | 2 | 4 | 1 |
| Conn.-New Haven | 18. 29. | 2 | 0 | 3 |
| Delaware, U. of | 54. 106. | 4 | 4 | 3 |
| Florida, U. of | 8. 41. 62. 68. 179. | 7 | 0 | 1 |
| Georgia, U. of | 42. 98. 138. 160. 170. 177. 211.
216. 220. 257. 260. 282. 304. | 14 | 17 | 9 |
| Hawaii, U. of | 5. 13. 114. | 5 | 3 | 1 |
| Idaho, U. of | 35. 79. 84. 151. 195. 210. 222.
269. 271. 321. | 12 | 9 | 7 |
| Illinois, U. of | 32. 33. 296. | 3 | 5 | 2 |
| Illinois, Southern U. | 88. 190. 295. 310. | 4 | 7 | 0 |
| Indiana-Purdue U. | 49. 86. 154. 162. 240. 286. 302. | 16 | 10 | 4 |
| Iowa State U. | 17. 196. 292. 298. | 7 | 10 | 10 |
| Kansas State U. | 96. 100. 104. 149. 325. | 3 | 3 | 1 |
| Kentucky, U. of | 273. 288. 289. | 3 | 2 | 5 |
| Louisiana State U. | 97. 166. 167. 188. 197. 214. 328. | 10 | 10 | 4 |
| La. Poly. Inst. | 15. 108. 128. 168. 283. | 9 | 1 | 1 |
| Maine, U. of | 3. 38. 144. 221. 251. 268. | 8 | 13 | 15 |
| Maryland, U. of | 43. 125. 139. 198. 319. | 7 | 5 | 4 |
| Massachusetts St.U. | 111. 215. 235. 258. 264. | 14 | 12 | 10 |
| Michigan, U. of | 12. 21. 22. 69. 146. 275. | 5 | 6 | 2 |
| Michigan State U. | 39. 55. 87. 145. 155. 209. 322. | 9 | 17 | 3 |
| Michigan Tech. U. | 66. 184. | 2 | 0 | 5 |
| Minnesota, U. of | 70. 85. 122. 123. 156. 175. 191.
213. 297. 308. 320. | 17 | 19 | 2 |
| Mississippi St. U. | 36. 165. 247. 248. 290. 299. 326. | 7 | 1 | 3 |
| Missouri, U. of | 25. 26. 76. 118. 278. 311. | 7 | 10 | 3 |
| Montana, U. of | 14. 40. 50. 52. 71. 109. 150.
192. 223. 238. 255. 330. | 12 | 18 | 10 |
| Nebraska, U. of | 101. | 2 | 2 | 0 |
| Nevada, U. of | 27. 82. 83. 237. | 2 | 3 | 0 |
| New Hampshire, U. of | 94. 143. 263. 314. | 5 | 3 | 0 |

| University or
Experiment Station | Progress Statement
numbers | Proj. Grad. Publ.
Sci. Stud. | | |
|-------------------------------------|---|---------------------------------|-----|-----|
| | | no. | no. | no. |
| N. J.-Rutgers U. | 242. | 2 | 0 | 0 |
| New Mexico St. U. | 153. 157. 207. 226. | 6 | 4 | 2 |
| N. Y.-Cornell U. | 127. 199. | 3 | 2 | 0 |
| N. Y.-Syracuse | 19. 44. 72. 183. 203. 254. 259. | 13 | 6 | 3 |
| North Carolina St. U. | 37. 45. 57. 91. 105. 110. 169.
252. 270. 287. 300. 306. 307.
316. | 19 | 19 | 11 |
| North Dakota St. U. | 103. | 3 | 5 | 0 |
| Ohio State U. | 4. 23. 74. 147. | 4 | 2 | 0 |
| Oklahoma State U. | 6. 59. 60. 93. 126. 137. 163.
164. 182. 256. | 11 | 4 | 4 |
| Oregon State U. | 28. 46. 47. 63. 77. 78. 113.
266. 280. 281. | 12 | 7 | 2 |
| Pennsylvania St. U. | 2. 112. 180. 234. 241. 272. 293. | 9 | 11 | 7 |
| Puerto Rico, U. of | 130. 140. 141. | 5 | 0 | 0 |
| Rhode Island, U. of | 206. 236. 243. | 4 | 5 | 2 |
| S. C.-Clemson U. | 20. 34. 61. 65. 81. 89. 158.
245. | 4 | 2 | 0 |
| South Dakota St. U. | 102. 228. | 3 | 1 | 0 |
| Tennessee, U. of | 7. 90. 159. 189. 217. | 10 | 3 | 1 |
| Texas A&M U. | 129. 136. 250. 327. | 7 | 4 | 2 |
| Utah State U. | 99. 176. 200. 201. 229. 231. | 6 | 6 | 1 |
| Vermont, U. of | 95. 142. 172. 218. 244. 323.
324. | 8 | 3 | 3 |
| Virginia Poly. Inst. | 178. 204. 301. 315. | 7 | 8 | 1 |
| Washington, U. of | 1. 16. 80. 117. 152. 202. 246.
261. 274. 276. | 11 | 14 | 2 |
| Washington State U. | 56. 124. 193. 232. 265. 267. | 10 | 2 | 3 |
| West Virginia, U. of | 64. 171. 253. 291. 294. | 6 | 7 | 1 |
| Wisconsin, U. of | 30. 73. 115. 148. 312. 313. | 9 | 7 | 14 |
| Wyoming, U. of | 67. 121. 224. 225. | 4 | 2 | 2 |
| Totals | | 421 | 361 | 195 |



● LOCATIONS OF THE INSTITUTIONS CERTIFIED TO PARTICIPATE IN THE McINTIRE-STENNIS COOPERATIVE FORESTRY RESEARCH PROGRAM
(DARK REGIONS REPRESENT FORESTED AREA)

